

Chapter 4

Important Range Plants

PROMISING GRASSES

Reseeding depleted ranges with improved grasses has been extensively practised all over the world. Pasture establishment with cultivated grasses has involved millions of hectares in Australia, Europe, New Zealand and the western United States. A few indigenous and exotic grasses that have performed well in various range ecological zones of Pakistan can be recommended for large-scale reseeded in the relevant ecological zones of the Hindu Kush-Himalayan region.

Agropyron Cristatum (Crested Wheatgrass): This is a perennial tufted bunch grass with stems up to 1 m. Some stems are fine and have several leaves while other stolons are coarse with fewer leaves. Leaves are linear and are 5-15 cm long and 2-5 mm wide. Ligule is up to 1.5 mm wide membranous, often fringed or lanceolate. It produces very dense root system up to 2 m deep. Inflorescence is a dense spike 2-5 cm long and 0.7-2.0 mm wide. Each spikelet contains 3-8 flowers which are sessile (Basel and Berlin, 1981). Seeds shatter soon after maturity and seedlings germinate readily so the initial thin stand soon becomes thicker. Seeds also remain in dry soils for a long period until the moisture is adequate for germination.

The species originated in central Asia, eastern Russia and Siberia and was introduced to Canada, USA, Europe and New Zealand. Crested wheatgrass is quite popular because it establishes and grows well under adverse conditions. It is adapted to dry conditions with 125-300 mm annual

rainfall. It has also been found in areas where there is less than 50 mm annual rainfall. It grows up to 2500 m. The grass is hardy and becomes dormant during prolonged dry periods and recovers soon after rainfall (Mohammad, 1981). It is also frost tolerant (Walton, 1983). It grows well on mostly good soils including light textured sandy soils and heavy clays. It tolerates only a short period of spring flooding and is intolerant of high water tables and is sensitive to salinity.

Crested wheatgrass is best suited to pasture production. It can be grazed heavily without reducing its productivity. It is of special importance because it is ready for grazing from early spring (Hughes et al., 1969). It grows very rapidly in May and June, so it produces grazing material when feed is in short supply and responds well to early grazing. During its early vegetative stage, it may contain 14-17 percent crude protein but at maturity the plant contains only 8 percent crude protein. Its quality and palatability also decreases during hay-making (Walton, 1983). After flowering, it does not meet the nutritional requirements for protein. Regrowth after hay cutting is also poor. About 5 cm of the growth should be left ungrazed at the end of the season.

It can produce forage for as long as 40 years. Plantings of 1913 in the USA still exist. Seed production of 1000 kg/ha has frequently been recorded. The species is quite variable in terms of seed size and germination percentage because its inflorescence is cross pollinated (Hughes et al., 1969).

In Pakistan crested wheatgrass is inter-cropped with many winter legumes, e.g. alfalfa and vetch for pasture and hay. It has been introduced at NARC, Islamabad, Peshawar, Mastung, and in the Northern Areas. It is well adapted to the mediterranean climate of Baluchistan. At Mastung, it has yielded 4.2 t DM/ha (Muhammad and Bhatti, 1983). It has a high potential for reseeding in the high mountains of Baluchistan and the Northern Areas.

Bothriochloa Pertusa (Palwan): It is commonly known as 'Palwan' or Hurricane grass. It is a tufted perennial with stolons and rhizomes. Culms are erect or geniculate up to 1 metre tall. Basal diameter is about 7 mm with 8-12 tillers. The leaves are linear and mostly basal. The flowering stems terminate in 6-10 radiating brownish seed spikes.

Palwan' is well distributed in South East Asia, tropical Africa and Arabia. In India, it occurs all over the country up to 2100 m (Dabadghao and Shankarnarayan, 1973). It is a native grass of Pothwar Plateau and Himalayan forest grazinglands. It is adapted to a wide range of climates from sub-tropical sub-humid to humid ecological zones with annual rainfall range of 500-1300 mm. The grass is drought tolerant and can be successfully grown on dry areas. It grows on a variety of soils from coarse to fine textured and moderately acidic to slightly alkaline with a pH of 5.8 to 7.5. It prefers fertile soils and can be successfully grown in the dry areas (Pathak and Jakhmola, 1984). Seed is sown along contour trenches, pits or on flat

lands at a rate of 3 kg/ha. It is a good soil binder.

Tufts are planted in the highly eroded hilly areas in Pothwar Plateau and Tarbela watersheds. It can withstand heavy grazing and short dry spell. Tufts planted at 50 cm intervals can cover soil within a growing season. Planting is done at the beginning of monsoon rainfall season.

At NARC, forage production upto 10 t DM/ha was obtained from two cuttings. Under natural conditions in Islamabad about 4-8 t DM/ha are cut for hay. It is a palatable grass grazed by sheep, cattle, buffaloes and goats. It has considerable potential for soil conservation in the Pothwar area.

Cenchrus Ciliaris (Dhaman): Locally known as 'Dhaman' or Buffelgrass, it is a summer growing perennial; culms 20-50 cm tall are erect or decumbent, and branch from the base. Growth forms vary from rosette or procumbent to erect. The stems reach up to 1.5 m height at maturity, and have typical foxtail seed heads; leaves are 10-25 cm long, 3-7 mm wide, glabrous or hairy, ligule narrow, ciliate membranous. Inflorescence is a dense cylindric raceme 3 to 10 cm long, pale or purplish. The seeds are dimorphic, differ in size and weight, and are enclosed in clusters of bristles which are dispersed by wind at maturity. Seeds remain dormant for a period of 9-12 months. Buffelgrass has fairly a deep root system, which is dirty brown in colour and thin. The number of rootlets increases with age. The root system is well distributed in the surface and middle zones. Das et al. (1963) reported that about 50 percent of the roots penetrated below 1 m. By virtue of its deep root system, it is highly drought resistant and can withstand heavy grazing or burning.

Buffelgrass is native to tropical and sub-tropical Asia, Africa and Latin America. It has been extensively seeded in Australia. Some of the prominent cultivars developed in Australia are 'Biloela' 'Molopo' 'Boorara' 'Lawes' 'Nunbank' 'Tarewinnabar' 'Gayandah' 'American' and 'West Australian'. Buffelgrass is also common in the southeastern part of the United States. In Pakistan, local cultivars 'Dhaman Sofaid' and 'Dhaman Kala' are extensively found in Pothwar scrub ranges, Salt Range, Pabbi Hills, Thal, Cholistan, D.G. Khan, Kohistan, lowlands of Baluchistan and Tharparkar Desert. A new cultivar 'Blue Buffelgrass' developed by the author at NARC, Islamabad, yields about 30 percent more than 'Dhaman Sofaid' in Pothwar scrub ranges. For Indian Rajasthan Desert, varieties '358' and '3108' have been recommended by Shankarnarayan and Shankar (1984). Some other species of this genus, such as *C. biflorus* and *C. setigerus*, also occur in the arid and semi-arid tropical areas of Pakistan and India (FAO, 1975).

Buffelgrass is suitable for areas with rainfall of 350-800 mm and an altitude of 1000 m. It prefers light textured sandy loam soils but is also adaptable to harder and heavy textured scrub soils. Seeds of *Cenchrus ciliaris* sown during spring do not do well as the growth season is very short. Seeds germinate well but due to very hot season, the plants cannot get established, and die. Seeding is recommended immediately before the onset of

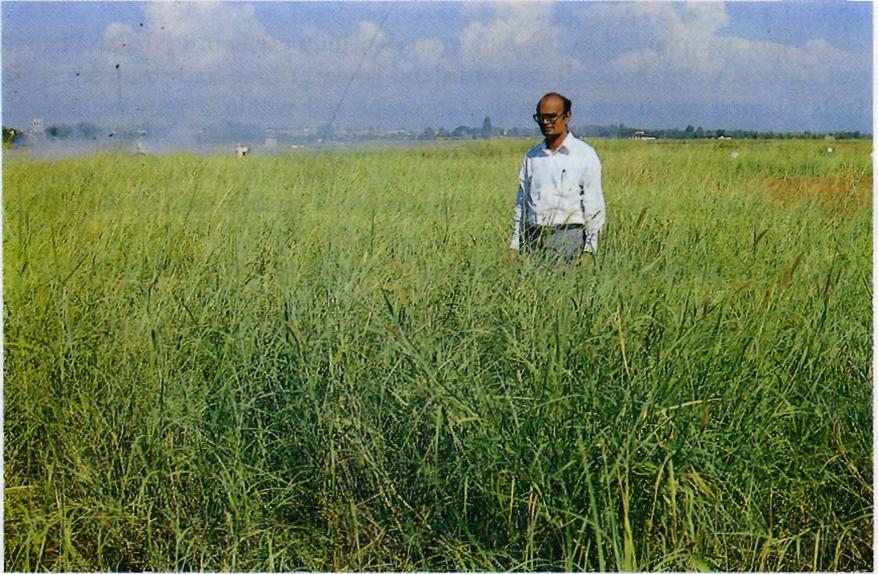


Plate 14. Blue-Buffel (*Cenchrus ciliaris*) - a new selection for Pothwar scrub ranges.

monsoon season (Mohammad et al., 1984). Seeding at the rate of 3-5 kg/ha is done on disked and cultivated land. In Thal, sowing at the beginning of summer monsoon rainfall season was very successful (Khan, 1965). Broadcasting is preferred over drilling because fluffy nature seeds tend to clog in seeding drills. Seeds are covered with 0.5 to 1.0 cm soil by dragging brush drawn either by a camel or tractor. seeds germinate within 10 days, provided soil moisture is adequate. Another 30- 40 days are required for seedling establishment.

Tuft planting and transplantation of seedlings has also been successful on sand dunes in Thal and eroded lands in Pothwar Plateau (Khan, 1968, Mohammad, 1984). In Peshawar rangelands buffelgrass was interseeded with *Eucalyptus camaldulensis* while in Thal rangelands, there are huge pastures of *Cenchrus ciliaris* and *Lasiurus indicus* mixture. These seedings increased productivity from 300 to 1800 kg DM/ha per year (Khan, 1970). Buffelgrass is also intercropped with different legumes to improve forage quality (Sultani et al., 1985). Mixed seeding with *Lasiurus indicus* is quite desirable in desert rangelands (Government of India, 1981). Buffelgrass has been interseeded with *Leucaena leucocephala*, *Atriplex nummularia* and *Zizyphus nummularia* on thousands of hectares in Kohistan rangelands (Mohammad, 1987). Under heavy grazing, the reseeded area can be invaded by *Cymbopogon jawarancosa*. About a year is required for stand establishment before livestock grazing can be allowed. Buffelgrass is highly palatable and relished by sheep, cattle and goats.

Buffelgrass remains productive for a long period. Pastures reseeded with this grass during 1965-66 in the Thal area still yield about 3.5 t DM/ha, although seasonal grazing has been done every year since their establishment. Mohammad and Naqvi (1987) obtained forage yield from buffelgrass during an 8-year study at Dhabeji. The annual fluctuation in forage yield was primarily due to variation in annual rainfall. During the past 10 years, intensive adaptation trials of more than 40 cultivars collected from different countries of the world have been carried out in various areas. The cultivars selected for different areas are RM 269 in Peshawar Valley, Blue Buffel in Pothwar Scrub Ranges, Sofaid Dhaman in Thal, Cholistan and D.G. Khan Ranges and Kala Dhaman' in Kohistan Ranges and Baluchistan lowlands.

Quality of buffelgrass varies with the stage of growth. In a study by the Range Research Project Lohi Bher, crude protein was 9.62 percent at pre-bloom 7.87 percent at flowering and 4.37 percent at maturity (Mohammad et al, 1986). Production was substantially increased by the application of nitrogenous fertilizer. Application of N-fertilizer at 100 kg/ha produced 5.42 t DM/ha and 44.14 kg/ha of seed whereas only 3.35 t DM/ha and 4.25 kg/ha of seed were produced when the fertilizer was not applied (Mohammad and Bhatti, 1983). However, fertilization during the spring did not increase forage production. Forage production of buffelgrass is also affected by the frequency of cutting. At NARC, buffelgrass yielded 13.5 t DM/ha when 100 kg N/ha was applied during the summer and cutting interval was 20 days compared to 7.8 t DM/ha with only one final cutting and no fertilizer. In a sheep grazing trial at Lohi Bher Range in the Pothwar Plateau, sheep gained 3.7 kg (live weight) on improved pasture and 1.9 kg on open/depleted range (Mohammad et al., 1986). Dabadghao and Shankararayan (1973) reported that a well established buffelgrass pasture could carry about 450 sheep per 100 ha in Rajasthan Desert ranges. Buffelgrass is the most suitable for the tropical desert areas where forage production can be substantially increased with improved cultivars.

Chloris Gayana (Rhodesgrass): This is a tufted perennial that grows during the summer. Its stem is 50-150 cm tall and it has a linear leaf blade 20-40 cm long and 3-9 mm wide, that tapers to a fine point. Its ligule is up to 6 mm wide and has a hairy membranous ring. Inflorescence is composed of 7-15 brownish green spikes, sometimes in two whorls, each 8-15 cm long. Each spikelet is 3-4 mm long, sessile and ciliated (Basel and Berlin, 1981).

Although native to Africa, rhodesgrass is widely adapted to sub-tropical and temperate areas. It is common in Australia, Pakistan and India. In Australia, Katambora', Callide' and Samford' are promising cultivars, grown on large areas (O'Rielly, 1975). In Pakistan, Kenyan cultivars are grown in the Pothwar scrub ranges. Several species of *Chloris* genus occur naturally in Indian Punjab, Rajasthan and Utter Pradesh. The annual rainfall requirement is 600-1200 mm with an altitude up to 1500 m. It has a wide adaptation to soil types, from light to heavy textured sandy loams but prefers fer-

tile soils. It can be established from seeds and is also propagated vegetatively from root shoot. Although summer growing, it has moderate tolerance to frost. The grass disappears after three years of establishment in Sind arid areas (Mohammad and Naqvi, 1987). Adaptation trials conducted by the National Forage and Pasture Programme at Islamabad and Peshawar indicate that rhodesgrass can be seeded in sub-tropical sub-humid Pothwar scrub rangelands. Seed is sown in the beginning of the monsoon in a disked and cultivated seedbed. Line sowing is preferred over broadcast seeding. About a full summer growing season is required for plant establishment.

Rhodesgrass is palatable and can withstand heavy grazing and trampling. It is also used as hay but it is not recommended for silage. Digestibility and crude protein decreases as the grass matures and becomes old and stemmy. Seed rate for *Chloris gayana* is 6 kg/ha. Herbage yield up to 7.5 t DM/ha was recorded at NARC under rainfed conditions. It is intercropped with a number of legumes like lucerne (Gohl, 1981). The grass is also intercropped with *Atriplex canescens* which increases forage yield (Mohammad and Bhatti, 1983).

Rhodesgrass also responds well to N-fertilizer and more intensive clipping. With 100 kg N/ha and clipping at 20-day intervals the forage yield doubled. Winter fertilization, however, did not increase forage production. The grass is also salt tolerant. Mohammad et al. (1987) subjected plants to different levels of salinity. The grass tolerated up to 9.0 dS/m. Percentage survival of plants, plant height, number of tillers, leaf length, leaf area and dry weights of shoots and roots decreased with salinity. Uptake of Na, K, Zn, P and M increased and uptake of Fe decreased. There was an antagonistic effect between Na and K.

The grass can be reseeded over large areas in Pothwar and Himalayan foothills. It forms a good soil cover and may be used to control soil erosion. Its potential for silvi-pasture establishment needs to be explored.

Cynodon Dactylon (Bermudagrass): This is also known as Khabbal'. It is a summer growing perennial with extensive stolons and rhizomes that rapidly colonize bare ground and form a dense mat. Leaves are grey to bluish green, short and flat. Its leaf blade is 5-16 mm long and 2-5 mm wide. The emerging blade is folded in the bud shoot. Its ligule is 0.2-0.3 mm wide and is membranous with ciliated elm. Its inflorescence is composed of a whorl of 3-7 digitally arranged spikes radiating from the top of a slender peduncle, sessile flowers are 3-10 mm long; stems are erect and up to 12 cm tall (Basel and Berlin, 1981). The seed is very small and 1 kg may contain 3-4 million or more seeds. Germination percentage is quite low (Walton, 1983).

Bermudagrass is found in many tropical and temperate countries of Asia, Africa, America and Australia. It is native to the Pakistan-India sub-continent, and is found in Pothwar, Thal, D.G. Khan, Cholistan, Kohistan, Tharparkar and Baluchistan lowlands. It grows on all types of soils, abandoned cultivated lands, paths, roadsides and depressions. Growth is better

on heavy soil than on light soil because of fertility and soil moisture. However, well fertilized stands give good yields on sandy soils. It can withstand flooding but does not grow well in water-logged areas. It is not much affected by soil reaction and grows well both on acidic and alkaline soils (Hughes et al., 1969). It is adapted to areas with more than 600 mm annual rainfall and a mean daily above 24°C (Gohl, 1981). The grass can tolerate temperatures above 24°C (Gohl, 1981). The grass can tolerate grazing and trampling. It can withstand prolonged drought and remains dormant in cooler months. Regrowth is rapid in spring and summer. It is a good soil binder and is used extensively for soil conservation and for lawns.

Bermudagrass is very palatable and nutritious. Leaves at vegetative stage contain 12-14 percent crude protein. Weight gain in livestock is relatively higher (Hughes et al., 1969). However, it is a problem weed in arable cultivated land (Gohl, 1981). It is sown during spring or summer on well prepared seedbeds. Due to low germination percentage a seeding rate of 9-11 kg/ha is recommended. The grass can be established vegetatively by tufts, plugs or springs. For high yielding varieties, seed is sterile; therefore, only stem cuttings are planted (Walton, 1983).

At maturity, forage production declines and herbage becomes unpalatable. Summer and winter legumes, such as vetches and clovers can be intercropped to sustain year-round forage production. It also produces excellent hay. The grass responds well to fertilizers, especially nitrogen. This fertilizer should be applied when new stolons are 12-13 cm long. Digestibility of bermudagrass is 65 percent or higher.

Bermudagrass may be used to control soil erosion in Pothwar scrub ranges. Economical methods of planting tufts of the grass are needed. Selection of fast spreading cultivars may be given priority.

Dichanthium Annulatum (Murgha): This is locally called Hindigrass', 'Delhigrass' or 'Murgha' in India. The stems are erect or ascending, 45-120 cm long, with nodes that are usually bearded. Leaves are linear about 8 to 30 cm, finely acuminate, glaucous, glabrous, more or less sparsely hairy above with small bulbous based hairs; the margins are scabrid, with ligules nearly 0.3 cm long, oblong, obtuse membranous or shortly ciliate. Racemes are 2-3.5 cm long and subdigitate, fasciated, pinkish or nearly white (Dabodghao and Shankarnarayan, 1973). The flowering stems terminate in 4-6 radiating brownish seed spikes. The root system is characterized by dark brown hairy roots which increase with age. The roots penetrate to a soil depth of 120 cm. However, most of the roots are concentrated in the surface zone.

Murgha' a native grass of Pakistan, India, Nepal, Bangladesh and Burma. It also occurs in tropical Africa and Australia. A selection of *D. annulatum* ('Marvel-8') has been released in India for medium and low rainfall areas (Dabodghao and Shankarnarayan, 1973). It is extensively grown in Murree foothills, Pothwar Plateau and D.I. Khan. This grass prefers fertile loams but also grows on rocky grounds wherever sufficient soil moisture

is available. It has great potential in the Indus flood plains of D.G. Khan and D.I. Khan. It is sown during the summer. Germination occurs within a week. The plant matures within 60 days and can then be grazed or cut for hay. With irrigation, green forage yield up to 30 t/ha was obtained in six cuttings in India. Indian strain 'Marvel-8' yields about 13t/ha of dry matter under rainfed conditions. This strain is also suitable for protecting bunds and terraces in areas where rainfall is heavy.

Murgha' is palatable and leaves at vegetative stage may contain up to 10.4 percent crude protein; protein in mature grass decreases to only 2.7 percent. (Gohl, 1981). The grass has a great potential in the flood plains of the Indus in Rakh Miran (D. I. Khan). This is also a recommended species in the sub-tropical humid rangelands of the Pothwar Plateau of Pakistan (Mohammad and Bhatti, 1983).

Elymus Junceus (Russian Wildrye): This perennial grass is large, dark green, and is mostly basal with large ligules. The spike is borne on very long leafless culm up to 1 m long. The heads are dense terminal spikes with seeds that shatter readily on maturity. Therefore, seed collection is quite difficult. It has an extensive fibrous root system, which enables it to tolerate drought. The roots may penetrate to a depth of 3 m. About 75 percent of the roots are in the surface area (15 cm) but they can draw water horizontally from 1.5 m. Seedlings are small and very slow growing and establishment is quite difficult. However, germination percentage is high and seed remains viable up to 5-6 years. The plants should be allowed to mature and set seed before grazing.

Russian wildrye is native to Siberia, Russia and was introduced to Canada, the United States and Europe. It is well adapted to dry areas with annual rainfall of 125-300 mm. It is a very hardy species and is resistant to drought, frost and salinity (Walton, 1983). It can be grown on a fairly wide range of soils but does well on fertile loams. On sandy loam soils in the dry areas, the root system penetrates enough into the soil before the moisture is depleted. Mohammad (1979) has described it in detail. It has a very long growth period which starts early in the spring and continues until late fall.

Although grazing can continue from early spring to winter, it is better to graze the grass lightly in the spring and save most growth for summer and fall. It is very tolerant to grazing and regrows quickly after clipping. It is a highly palatable and nutritious grass with relatively high crude protein. It provides an excellent forage during August to November. It is the best cool season pasture grass to supplement the forage during winter (Hughes et al., 1969). Best forage and seed yield is obtained by the application of N-fertilizer. For seed production, wider spacing and heavy N-fertilizer application are recommended. The grass is mainly used as a pasture plant and is not recommended for hay.

For increased forage production, Russian wildrye is seeded in mixtures with legumes. In the United States, it is grown in combination with crested wheatgrass and winter fodder shrubs (Mohammad, 1982). It is also

intercropped with alfalfa for better feed quality (Walton, 1983). Yields are also increased by seeding mixtures with legumes. Seeding the legume in alternate rows or cross seeded rows also decreases competition. Winter introduction trials at NARC have been promising. It has also been introduced in Mastung (Baluchistan) where forage production is 1.5 t DM/ha (Mohammad and Bhatti, 1983). However, it has not been seeded on a large scale.

Russian wildrye needs to be introduced as winter forage crop in Pothwar. It appears to be suited for large-scale seeding in Northern Areas and high mountainous areas of Baluchistan.

Lolium Multiflorum (Italian Ryegrass): This tufted annual has cylindrical stems that are 30-100 cm tall and often erect branching at the base. It produces abundant dark green leaves. The leaves are rolled in the bud and are smooth. The leaf blade may be 6-20 cm long and 4-10 mm wide; linear with narrow auricles at the base. Its inflorescence is a slender spike, 10-40 cm long, composed of 5-8 spikelets, arranged on opposite sides. Spikelets are sessile, each with 10-20 flowers. The seeds have awns of various length (Basel and Berlin, 1981).

Italian ryegrass is native to the mediterranean region of southern Europe, north Africa and Asia. Now, it is grown in almost all parts of the world. The grass is adapted to a wide range of soils but produces best on soil of medium to high fertility. It also grows well on soils of low fertility but heavier seedings are necessary for good cover. It grows best on irrigated lands and in areas where annual precipitation is 500- 1000 mm. It can grow on wet soils, with good surface drainage. However, it is sensitive to waterlogging. The grass does not withstand drought or hot dry weather. It is also frost sensitive and does not survive severe winters.

It is an excellent grass for forage, soil improvement and erosion control. However, its primary purpose is forage. For pasture, it is grown alone or in combination with winter grains, thus allowing earlier grazing than Italian ryegrass alone. Intercropping of annual or perennial clovers improves both production and the nutritional value of the forage.

For seeding land is disked and the seed is broadcast. The seed is covered with 1-2 cm of soil. Seed is also drilled in rows into existing pastures at a seeding rate of 4-8 kg/ha. For soil conservation purposes, the seeding rate should be doubled. Mature seeds shatter readily and fall on the ground. They remain dormant during summer and germinate in the fall.

It is a very palatable and nutritious grass with forage yield of 5-10 t/ha of hay or 25 t/ha of silage. Mixed cropping with grain resulted in live weight gains in cows of over 500 kg per hectare in 6 months (Hughes et al., 1969).

Italian ryegrass responds well to nitrogen fertilizer. Herbage yield increases significantly by applying 30 kg N/ha. Quality and quantity of forage is also increased if legumes are intercropped. The grass is generally cut for

hay when the spikes are formed. Because of fine stem and abundant leaves, it makes an excellent hay. It should be cut at a stubble height of 7.5 cm. On a good soil and with adequate moistures, the pasture may also be grazed after hay cutting. It provides good grazing during winter and spring.

The grass has been introduced at Jaba, Muzaffarabad, in sub-tropical humid zone where it has yielded 1.5-1.7 t DM/ha and 100-150 kg/ha of seed (Amin and Ashfaq, 1983). There are introduction plots in the Swat and Hunza Valleys, in a dry temperate zone. At NARC, it has proved a good winter forage with a dry matter yield of 2.9 t/ha.

Lolium Perenne (English Ryegrass or Perennial Ryegrass): This short lived perennial bunch grass species has shallow fibrous root system. The stem is 30-60 cm tall and leafy. Leaf blade is 3-20 cm long and 2-6 mm wide. The leaves are linear, smooth and quite stiff, often with small auricles at the base margin. The leaves are folded in the bud. The membranous ligule is 1-2.5 mm long. Its inflorescence is a slender spike, 5-30 cm long, composed of 5-35 sessile spikelets. These spikelets are arranged on opposite sides of the stem. Each spikelet may contain 2-10 awnless flowers (Basel and Berlin, 1981).

Perennial ryegrass is native to temperate Asia and north Africa. It was the first perennial grass grown in pure culture for forage production in Europe. Now, it is grown for pasture all over the world. It is a winter hardy grass and requires 750-1250 mm of annual rainfall. It is adapted to a wide range of soils including heavy clay but prefers medium to high fertility soils. It is not a dryland grass and generally not adapted to areas with extremes of cold, heat or drought. It requires large amounts of water but is sensitive to waterlogging.

Perennial ryegrass can be seeded in early spring or fall. In areas where winters are severe, spring sowing is recommended; in areas where winters are mild, early fall sowing is recommended. Germination is better if it is sown in the late fall. Winter forage yield is low if severe freezing occurs, especially on heavy soils. Early spring seeding may be successful when summer is mild and rains are frequent. The seedbed is prepared with a light disc and seed should be broadcast. Optimum seed rate is 4-8 kg/ha. However, when grown in mixture with small grain crops for annual forage, 2-4 kg/ha seed is recommended. For erosion control, the seeding rate can be doubled.

Forage production is substantially increased if 30-50 kg N/ha is applied or when grown in mixture with legumes. Fall, spring and fall-spring applications are made according to the requirements. Perennial ryegrass is generally cut for hay after pollination or when the seed is soft. Because of its leafiness and medium fine stems, it makes a high quality hay. Under favourable conditions after hay cutting, the pasture can be grazed. Heavy pasturing is desirable to keep the grass in succulent condition (Hughes et al., 1969). This grass has been introduced in the Neelum Valley, yielding

1.6-1.8 t DM/ha and 125-175 kg seed/ha (Amin and Ashfaq, 1983).

Panicum Antidotale (Bluepanic): This erect summer-growing perennial grass is up to 3.0 m tall. Leaves are linear and blue green, leaf blades are 25-50 cm long and 5-12 mm wide. Its ligule is membranous and 0.5-2.0 mm wide. Seeds are produced in large panicles 20-45 cm long and 6-15 mm wide composed of many flowered ascending branches. Spikelets are 2.5-3.5 cm long (Basel and Berlin, 1981). Seeds shatter at maturity so seed collection is usually difficult. Seeds remain dormant for about a year.

Bluepanic is native to Pakistan, India, Nepal, Afghanistan and Sri Lanka. It is now extensively grown in several tropical countries in Asia, Africa, Latin America and Australia. Several other species such as *P. maximum*, *P. coloratum*, are also used for pasture establishment. It is well-suited to the sub-tropical sub-humid Pothwar Plateau, Salt Range, Pabbi Hills, Kharemurat and Gulial forests. It is also adapted to the Thal and Kohistan ranges (Mohammad and Naqvi, 1987).

Adaptation trials were conducted at NARC, Islamabad, Peshawar, Thal and Dhabeji during the past 13 years. Forage production in t DM/ha was as follows: Peshawar (5.3), Lohi Bher (8.8), Kherimurat (6.5), Pabbi Hills (7.0), Thal(5.2) and Dhabeji (6.2). Bluepanic sustains forage production for 5 years, before it should be replaced.

Bluepanic is best suited to fertile sandy loam soils in areas receiving 500-800 mm of precipitation and an altitude up to 1000 m. It is sown at the beginning of monsoon. The seeding rate is 2.5-3.0 kg/ha. The seedbed is disked and cultivated. Drilling is preferred for a uniform stand. In Pakistan, most seed is broadcast. Tuft planting is also common in hilly areas for soil conservation. The seeds need to be covered by a thin layer of soil. Germination starts within 8-10 days of seeding. A full season of growth required for plant establishment. Grazing is normally allowed in the second year. It is a palatable grass and can withstand heavy grazing by sheep and cattle. At late flowering stage, it acquires a bitter taste and accumulates oxalic acid, which can cause kidney disorders.

Forage production is significantly increased if nitrogenous fertilizer is applied. Application of 100 kg/ha of urea increased dry forage yields by 50 percent (Mohammad and Bhatti, 1983). Reseeding with bluepanic increased range productivity 12 times compared to depleted/open range in the Jamrud area of North Western Frontier Province (Mohammad and Bhatti 1983). The optimum seeding rate is 2.5 kg/ha which gave 1120 kg/ha of dry forage and 20 kg/ha of seed. Seeding 1 kg/ha produced 1015 kg/ha of dry forage while seeding 0.5 kg/ha produced 372 kg/ha during the first year. Almost same results were obtained in the Neelum Valley (Mohammad and Bhatti 1983). Livestock weight gain increased substantially on pasture reseeded with Bluepanic (Mohammad et al. 1986). In Kohistan ranges, bluepanic yielded the second largest amount after buffelgrass (Mohammad and Naqvi, 1987).

Planting tufts of bluepanic is more successful. However, further re-

search is needed to determine economical planting methods. Pothwar ranges and Murree foothills are highly suitable for large scale seeding. Research on better methods of seed collection is needed.

Pennisetum Purpureum (Elephant or Napiergrass): This summer-growing, tall perennial grass grows in clumps with 2-20 tillers. Tillers are canelike and may be 1.5 m tall and 2.5 cm thick. It has strong and erect stems; branches are produced from the axil of the leaf of main stem. It has a deep root system and is fairly tolerant to drought but is susceptible to frost. It also withstands acidity and may tolerate a pH of 4.0 (Walton, 1983). Its leaf blade is 60-120 cm long and 20-40 mm wide. If allowed to grow to maturity, it produces an inflorescence 8-20 cm long. Flowers may be solitary or in groups of 2-4, sessile in bisexual flowers and pedicellated in male flowers (Basel and Berlin, 1981).

Elephantgrass is native to tropical Africa and is grown in many other countries such as America, Brazil, Australia, Pakistan and India. In Australia, the cultivar 'Capsicum' is high yielding with thick succulent stems and a strong crown and has vigorous stooling ability. Elephantgrass has long been introduced in the irrigated areas. Bajra-Napier Hybrid is extensively cultivated for fodder. Variety A-146' from Taiwan has provided good forage yields at NARC and has been grown in the subtropical humid northern mountains of Pakistan. *P. orientale* is the only other species of this generation that naturally occurs in Pothwar Plateau.



Plate 15. Elephant grass (*Pennisetum purpureum*), A-146 recommended for Pothwar scrub ranges.

Due to absence of viable seeds, elephantgrass is propagated vegetatively by root shoots or stem cuttings that have a few nodes. It is planted during early monsoon in a well prepared deeply ploughed bed. Establishment is better if planted during rainfall at 50x50 cm spacing. Variety A-146' is most suitable for Pothwar Plateau where rainfall exceeds 500 mm. It grows best on deep soils of moderate to fairly heavy texture. It can tolerate short drought but does not withstand waterlogging.

Elephantgrass is of considerable importance in high rainfall areas of Pothwar. It is excellent for dairy cattle because of its rapid, tender growth and relatively high protein content. With fertilization and proper management, dry matter yields up to 40 t/ha has been recorded at NARC. It provides one cutting during the spring and 2-3 cuttings during the summer growing season. Forage production remains constant up to 4 years and declines later. Occasional fertilization with N, P and K is necessary to maintain soil fertility. Nitrogen fertilizer also improves the crude protein content. Applying of 120 kg N/ha under rainfed conditions produced 39.35 t DM/ha forage compared 18.22 t DM/ha for the control. Percentage of crude protein increased from 6.98 to 12.63 following application of 120 kg N/ha. However, the crude fibre content was not affected by N fertilizer (Mohammad and Bhatti, 1983). Frequency of cutting also affects forage production. During summer, more forage was produced at 20-day harvest intervals than at 40-day intervals or final cutting. Elephantgrass is also intercropped with legumes. Cowpeas intercropped with elephantgrass improve forage quality, especially the crude protein content (Mohammad and Bhatti, 1983).

As planting of elephantgrass is highly labour intensive, economical procedures need to be developed for stem cutting or tuft planting. Intercropping of winter vetch or annual medics with this grass may result in year-long forage production.

FODDER TREES AND SHRUBS

Trees and shrubs are an important source of feed for livestock. They offer certain advantages because of their productivity, palatability and nutritional quality; they also provide cover for wildlife, conserve soil, stabilize sand dunes, have considerable aesthetic and recreational values and have beneficial role in the ecosystem. However, they have always been viewed as of secondary importance by land managers. Range managers in Pakistan are generally interested in replacing shrublands with grasses. Foresters primarily emphasize the development of timber forests. Agriculturists want to replace shrublands with cash crops that offer earlier returns. They have succeeded in some areas but could not replace shrubs on large tracts of arid and semi-arid lands, which constitute over 60 percent of the area of the country.

An ecological review of the arid land vegetation indicates that morphological and physiological flexibilities allow trees and shrubs to survive in the harsh environment of the desert and to survive ruthless exploitation by

man. Shrubs of the arid and semi-arid regions usually possess small, leaves which reduce transpiration losses. Large cell size, thick cell walls, a dense vascular system, high stomatal density and proportionally greater palisade tissues also reduce water losses. The volume of intercellular space is less in xeromorphic than mesomorphic leaves, but the ratio between the internal exposed surface area of the leaf and the external surface area is higher in xeromorphic leaves.

Plants shed their leaves to maintain the water balance. Leaf shedding usually begins with the oldest leaves and progresses toward the apical meristems. Shedding of leaves is correlated with seasonal changes in soil moisture. In the desert, leaves are often replaced by brachyblasts, reduced to stipules or shed completely during the dormant season. Certain desert shrubs reduce the weight of their young shoots through desiccation. Most of the shrubs continue photosynthesis through their stems and branches. Desert shrubs also develop a wide cortex that protects vascular tissues from desiccation. Shrubs also have an extensive root system that penetrates deep into the soil. Roots as long as 55 m below the soil surface for *Prosopis cineraria* were reported in the (Government of India, 1981). Some of the native shrubs and grasses are highly salt tolerant and drought resistant and may be sited to irrigated as well as arid range areas. Most of our desert rangelands have a very deep ground water table. Deep root systems allow shrubs and trees to this water efficiently. Water utilizing efficiency of shrubs with respect to the depth of ground water (Dakshini, 1972) is given in Figure 4. Several shrubs have the ability to utilize very saline water. The salt tolerance of various plant communities native to the Pakistan-India subcontinent were studied by Chatterji and Gupta (1969) and is diagrammed in Figure 5. Such shrubs can be successfully planted in desert areas of Thal, Cholistan and Tharparkar. Juneidi and Huss (1978) have recommended large scale planting of *Atriplex nummularia*, *A. canescens*, *Salsola foetida*, *Indigofera oblongifolia*, *Zizyphus nummularia*, and *Prosopis cineraria* in the semi-arid areas of the Arabian Peninsula.

A FAO report (1975) on Range Management in Sind strongly recommended planting of fodder trees and shrubs in the arid rangelands of Kohistan and Tharparkar. Among the native species, *Prosopis cineraria*, *Acacia nilotica*, *Tecoma undulata*, *Acacia senegal*, *Zizyphus nummularia*, *Calligonum polygonoides*, and *Indigofera oblongifolia* are suggested for the revegetation of arid areas of Sind. Planting of exotic species such as *Acacia aneura*, *Atriplex nummularia* and *Opuntia spp.* was also recommended.

During the past few years, fodder plants such as *Leucaena leucocephala*, *Atriplex nummularia* and *Opuntia spp.* have been successfully planted in the Kohistan tract. *Zizyphus nummularia*, *Z. mauritiana* and *Prosopis cineraria* were planted by Khan (1968) over large areas in the Thal ranges. The National Forage and Pasture Research Programme is dry planting fodder trees and shrubs at Dagar Kotli. These fodder trees and shrubs are *Tecoma undulata*, *Cordia mixa*, *Prosopis cineraria*, *Parkinsonia aculeata*, *Acacia modesta*, *A. aneura*, *A. tortilis*, *Zizyphus mauritiana*. Spac-

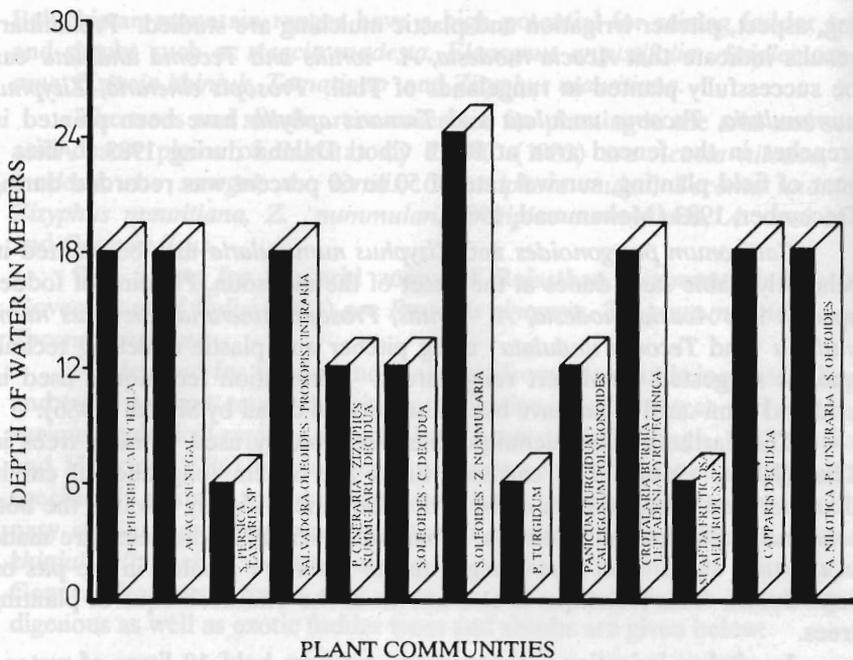


Figure 4. Gound water utilization efficiency of desert shrubs (Dakhshini, 1972).

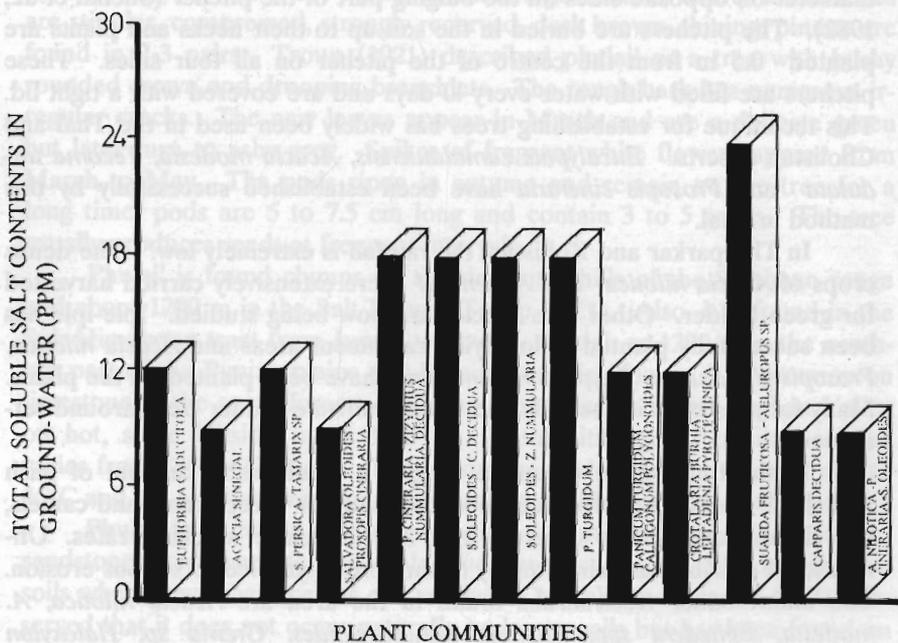


Figure 5. Salt tolerance levels of desert shrub communities (Chatterji and Gupta, 1969).

ing, aspect, pitcher irrigation and plastic mulching are studied. Preliminary results indicate that *Acacia modesta*, *A. tortilis* and *Tecoma undulata* can be successfully planted in rangelands of Thal. *Prosopis cineraria*, *Zizyphus nummularia*, *Tecoma undulata* and *Tamarix aphylla* have been planted in trenches in the fenced area at Rakh Choti Dalana during 1983. After 1 year of field planting, survival rate of 50 to 60 percent was recorded during December, 1983 (Mohammad, 1984).

Calligonum polygonoides and *Zizyphus nummularia* may be planted in relatively stable sand dunes at the onset of the monsoon. Planting of fodder species like *Acacia modesta*, *A. tortilis*, *Prosopis cineraria*, *Zizyphus nummularia* and *Tecoma undulata* using pitcher and plastic mulching techniques is suggested for desert range areas. Forestation techniques used in arid and semi-arid areas have been discussed in detail by Sheikh (1986).

The earthen tube technique has been widely used to raise trees in Thal (Khan, 1966). The earthen tubes are 30 cm long and 10 cm in diameter and open on both ends. The tube tapers slightly towards the bottom and facilitates soil retention. Four holes 0.5 cm in diameter are made in the tube shell. The tube along with the plant are planted in the pits on sand dunes. This technique is also known as the Thal technique of planting trees.

In pitcher irrigation, country-made pitchers hold 10 litres of water. To reduce the percolation rate of water, the pitchers are usually coated with paint or charcoal along all the sides except for circular areas of 3 cm diameter on opposite sides on the bulging part of the pitcher (Sheikh et al., 1982). The pitchers are buried in the soil up to their necks and plants are planted 0.5 m from the centre of the pitcher on all four sides. These pitchers are filled with water every 10 days and are covered with a tight lid. This technique for establishing trees has widely been used in the Thal and Cholistan deserts. *Eucalyptus camaldulensis*, *Acacia modesta*, *Tecoma undulata* and *Prosopis cineraria* have been established successfully by this method in Thal.

In Tharparkar and Kohistan, the rainfall is extremely low. The dense crops of *Acacia nilotica* and *A. senegal* were extensively carried harvested for green fodder. Other tree species are now being studied. Iple-iple has been successfully planted in low lying catchment areas and *Acacia nilotica*, *Prosopis glandulosa*, *Zizyphus nummularia* have been planted on the plains. Many farmers both in the hills and plains cultivate fodder trees around settlements.

In the Baluchistan mountain ranges, a considerable amount of bush and shrub growth has provided good browsing for sheep, goats and camels, but these stands have suffered from the excessive stocking rates. Unrestricted grazing has ruined many of the forests and led to serious erosion. The main fodder trees/shrubs found in the area are *Acacia nilotica*, *A. modesta*, *Ephedera* spp, *Fraxinus xanthoxyloides*, *Grewia* sp, *Haloxylon griffithii*, *Pistacia khinjuk*, *Prunus eburnea* and *Zizyphus mauritiana*.

The Trans-Himalayan grazinglands, Sulaiman mountain ranges and

Baluchistan mountain ranges have a high potential for raising fodder trees and shrubs such as *Acacia modesta*, *Elaeagnus angustifolia*, *Atriplex canescens*, *Pistacia khinjuk*, *Tamarix sp* and *Zizyphus mauritiana*.

The trees and shrubs, recommended for planting in the arid and semi-arid desert plains of Pakistan by PARC (1983) are *Acacia nilotica*, *A. modesta*, *A. senegal*, *A. tortilis*, *Commiphora mukul*, *Tecoma undulata*, *Zizyphus mauritiana*, *Z. nummularia*, *Atriplex nummularia*, *A. polycarpa* and *Opuntia ficus*.

The plants for the arid zones of Rajasthan, recommended by the Government of India (1981) are *Prosopis cineraria*, *Zizyphus mauritiana* and *Tecoma undulata*.

As demand for fodder and fuelwood from rangelands increases shrubs and trees warrant comprehensive investigation. Fodder trees and shrubs in various ecological regions of India have been studied (Singh, 1982; Parkash and Hocking, 1986) but information about some of the promising species specifically adapted to Pakistan environments is limited. Therefore, preliminary studies on species such as *Acacia modesta*, *Olea ferruginea*, *Pistacia khinjuk*, *Hippophae sp*, *Artemisia sp* etc., should be initiated immediately. General features, growth characteristics and uses of a few promising indigenous as well as exotic fodder trees and shrubs are given below:

Acacia Modesta (Phulai) : Family: Leguminosae; Common name: Phulai. It is a medium-sized deciduous, slow-growing tree which attains a height of 6 to 9 m. Young shoots are glabrous or nearly so. Prickles are stipular, compressed, strongly recurved, dark brown, shining; pinnae are found in 2-3 pairs. Troup (1921) described phulai' as a tree with bushy rounded crown and drooping branchlets. The rough bark has numerous irregular cracks. The new leaves appear in March and are a delicate green but later turn to ashy grey. Spikes of fragrant white flowers appear from March to May. The pods ripen in autumn and remain on the tree for a long time; pods are 5 to 7.5 cm long and contain 3 to 5 seeds. The tree usually produces seeds at frequent intervals.

Phulai' is found clumps on the dry outer hills of the Sulaiman range and about 1200 m in the Salt Range (Troup, 1921). Also, it is found in the Sub-Himalayan tract from Jumna westward, as high as 1200 m in the northern part of the Punjab plains and Baluchistan. In Hazara, it is common on limestone in the scrub forests of Khanpur and occurs in the Kaghan Valley on hot, shale hillsides upto 1466 m. Within its natural habitat, rainfall varies from 380 to 1270 mm. The maximum shade temperature may rise to 45°C and the absolute minimum may drop to well below the freezing point.

Phulai' is found on various geological formations, including limestone, sandstone, conglomerate and shale, and can grow in infertile dry, shallow soils where few other species can survive. Quraishi and Ahmed (1973) observed that it does not occur naturally on loamy soils but has been found on the eroded low hilly areas of Khairabad, Nowshera and Chitral (Shahid and Qayyum, 1977). Troup (1921) found that phulai' may occur in pure stands

or in association with *Olea ferruginea*, *Acacia catechu*, *Tecoma undulata*, *Prosopis cineraria*, *Bauhinia variegata*, *Zizyphus mauritiana*, *Ehretia laevis* and various other species, often with an undergrowth of *Dodonia viscosa*, *Carissa italica* *Adhatoda vasica* and other shrubs.

The distribution of phulai' extends into the lower limits of *Pinus roxburghii* in some parts of outer Punjab hills. On poor dry locations at low elevations it is sometimes associated with *Salvadora oleoides* and *Capparis aphylla*.

Champion (1935) classified phulai' as a component of the sub-tropical dry evergreen forest, in which kau' and 'phulai' are two typical tree species. He explained that the development of forest was arrested due to the severe biotic influences of the past and would not return to climax conditions without sufficient protection. Phulai' has been regenerated on thousands of hectares in Punjab. Its seed is generally sown in trenches, pits, troughs, etc., With standard dry forestation techniques, Sheikh (1986) found that it could be successfully planted where the average rainfall was 350 mm with or without mulch.

Troup (1921) observed that the tree is drought resistant. It coppices well and is usually managed by a silvicultural system known as "coppice-with-standard". The coppice shoots, as well as seedlings, must be protected from browsing, as they damaged by goats, sheep and camels.

Champion (1935) said the dry deciduous scrub forest is a seral type of the northern thorn forest. He believes that those forests have been subjected to long continued grazing, lopping and felling to the extent that they probably never attained climax status and never will. In another study, Said (1951) mentioned that, in the normal succession cycle, phulai' seemed to be sub-climax species, whereas kau' was more characteristic of a stable climax stage. Natural forests of phulai' are worked on 30-year felling cycle and 60-year rotation when trees reach a diameter of 20 cm and a height of 7 m (Sheikh, 1986).

Phulai' is one of the most valuable forage species due to its palatability and nutritional value. It is relished by all classes of livestock and many species of wildlife. It is also used for timber and fuelwood. It provides excellent flowers for honey production. Khan (1965) found that phulai' forage is rich in nutrients and also liked by wild ungulates, such as Nilgai in the Changa Manga forest plantations.

Acacia Nilotica (Babul): Family: Leguminosae; Common names: 'Babul' and 'Kikar'. It is a moderate to large sized, almost evergreen tree with a short trunk, a spreading crown and feathery foliage. Bark is dark brown, nearly black and hard inside with regular deep longitudinal fissures, which often run spirally up the tree. Young branches are green with white stipular spines, as long as 6 cm (Khan, 1965).

Babul' forests are mainly confined to the lower Sind though sporadic trees are found over the Indus Plains, Pothwar Plateau, Sulaiman foothills, in the lowlands of Baluchistan, Rajasthan, Haryana, Punjab and semi-arid

and arid parts of Deccan Plateau. It is as high as 600 m on flat, gently undulating ground or ravines. The maximum shade temperature of its habitat ranges from 40 to 50°C and the minimum temperature is from -1 to 15°C; the mean annual rainfall is from 400 to 800 mm. In areas with less rainfall, it can grow only with artificial irrigation or river inundation. In Sind, the species grows on riverain alluvial sandy loam soils subject to inundation. It is damaged by frost and is not found in areas where frost is a regular feature (Hussain, 1977). It is salt tolerant but does not tolerate water-logging for longer periods.

There appear to be two varieties of the tree **In Pakistan**:

i. **Telia'**: This variety has spreading crown and long pods. This is the variety found mostly in the riverain forests of Sind, Punjab and NWFP.

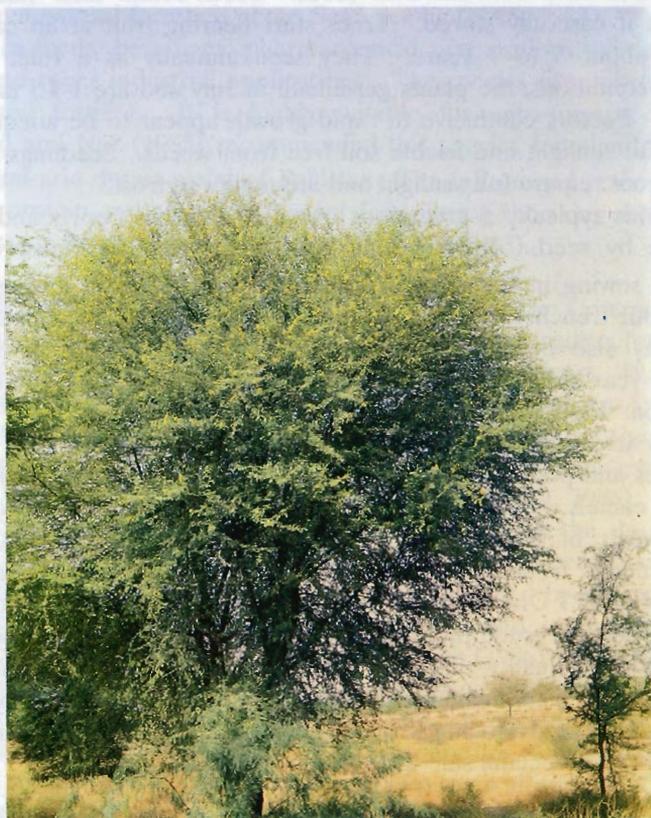


Plate 16. Babul (*Acacia nilotica*) - a fodder and fuelwood tree of the Indus Plains.

ii. 'Cupressiformis': ('Kabuli Kikar') This variety has broom-like ascending branches. It occurs sporadically along roadsides and in cultivated fields in Sind and Punjab.

Babul' is semi evergreen though on very poor soils it is sometimes bare for a short time in April-May. The young leaves appear from March to May; the old leaves commence to fall before they appear and continue to fall while the young leaves are sprouting. Flowering is generally in the rainy season, from June to September or October, but trees may be found in flower as late as December to January. The young fruit develops rapidly and ripens according to locality, but usually ripens from April to June. In Sind, the tree flowers twice a year; once in June-July and again in November-December. The pods from the first flowering ripen around October, but are usually poor in quality and quantity. Pods of the second flowering ripen in May and give a better crop. The pods are 5-15 cm long and 1.27 cm broad and each contains 8-12 seeds. Seeds retain their viability for some years if carefully stored. Trees start bearing fruit at an early age, usually at about 5 to 7 years. They seed annually as a rule. Under favourable conditions, the plants germinate in July and are 1-1.5 m high by December. Factors conducive to rapid growth appear to be adequate soil moisture, full sunlight and friable soil free from weeds. Seedlings produce a long tap root require full sunlight and are tender to frost.

Babul' is typically a gregarious tree. It coppices poorly and can be propagated by seed. Broadcasting is the cheapest and most effective method of sowing in the riverain forests of Sind. Direct sowing in pits, along contour trenches, furrows, dribbling of 3-4 seeds in lines, patches and mounds has also been successful in Pothwar. To ensure plant establishment, 1-year old seedlings raised in polythene bags are planted during the monsoon. Plantations are managed by clear felling a 20-25 year rotation followed by artificial regeneration, (Parkash and Hocking, 1986).

Leaves and pods of babul' are largely used as fodder for cattle, goats, sheep and camels. Annual pod yield has reached 4.2 t/ha of pods from riverain forests of Sind (Gori 1957). Singh (1982) reported 8-10 t of pods/ha per year from well stocked plantations. He further reported that forage yield of 5.27 DM t/ha were obtained from its leaves. Pods contain as much as 15 percent crude protein. The tree is also used for fuelwood. The timber is of good quality. Its bark contains as much as 27 percent tannin. Babul' gum is used for manufacturing matches, inks, paints and in confectionery (Parkash and Hocking, 1986). The tree is planted by farmers in compact blocks to reclaim salt- affected land (Sheikh, 1986).

Acacia Senegal ('Khor'): Family: Leguminosae; Common name; 'Khor'. It a small to medium sized thorny tree that grows up to 13 m in height. Bark is pale greenish grey, smooth on older stems, and falls off in thin flakes. Leaves are pinnate with pinnae in 3-5 pairs; stipular spines 3, compressed slightly recurved. Flowers are fragrant; if produces flat pods 2-

3 cm by 3 cm that are straight (Khan, 1965). It is found in dry rocky hills of Sind, Punjab and Baluchistan (Khan, 1965). The species is also found throughout the Sahelian zone from Senegal to Somalia. It is cultivated in Pakistan, India and Nigeria (NAS, 1983).

Khor' grows under sub-desert conditions where annual rainfall is as low as 200 mm, with 8-11 dry months in a year, but prefers 300-450 mm rainfall. In the Tharparkar Desert the tree grows where temperatures range from -4 to 48°C. It can survive the most adverse conditions; hot, dry winds and sand storms on the poorest soils of rock and sand. This species is ideal for the reclamation of refractory sites and shifting sand dunes (NAS, 1983).

Khor' is easily raised from seed. Its natural regeneration in existing stands is often poor but it regenerates easily in fallow lands and some degraded soils, often from stump coppicing. Planting of 2-year-old nursery raised seedlings is quite successful. For effective germination, seed should be soaked in water for 12 hours before sowing.

Khor' provides excellent firewood and charcoal. Average production of wood from natural forests is about 5 m³ per ha (NAS, 1983). It provides gum used in feeds, beverages, pharmaceutical preparations, confectionery products and other industrial applications. The species fixes nitrogen and improves soil fertility. It is highly suitable for agro-forestry systems. Mohammad and Naz (1985) recommended this species for planting in the arid and semi-arid desert plains of Pakistan. The foliage and pods of Khor' are rich in protein and are an important feed during the rainy season and early dry season for camels, sheep and goats (NAS, 1983).

Acacia Tortilis ('Jangli Babul'): Family Leguminosae; Common name Jangli babul. It is a small thorny tree 4-20 m high; its evergreen forage has white to creamy flowers. Fruiting starts at the age of 6-8 years. It is native to North Eastern African deserts, the Middle East, and southern Arabia. It grows in savanna formations or as a single tree on the edges of the depressions where water collects from the hillsides. It has been extensively planted in the arid lands of India (Parkash and Hocking, 1986). Sheikh (1986) reported successful forestation of jangli babul' in the desert rangeland of Thal at Dagar Kotli and at Dhabeji by applying special rain-water harvesting techniques. The plants can also be established by the pitcher irrigation technique (Sheikh, 1986). The tree is found in extremely dry climates receiving less than 100 mm rainfall. Sheikh (1986) reported that *A. tortilis* is a valuable addition to the known tree species that can be planted in desert areas where rainfall is 200 to 350 mm. It can survive maximum temperature exceeding 50°C and minimum temperature of close to 0°C. It regenerates from seed and coppices. It grows up to an altitude of 900 m. It favours alkaline soils with a pH of 7.95 to 8.30 (Parkash and Hocking, 1986). It is sensitive to frost and even 3-year-old trees around Peshawar died due to exceptional frost during the winter of 1982-83 (Sheikh, 1986).

Jangli babul' can be propagated by seed sown in pits during July-August. However, planting seedlings raised in polythene bags during the

monsoon is more successful. To stabilize sand dunes, 6-9 month-old seedlings are planted along mulched lines and watered 5-6 times during the first year (Parkash and Hocking, 1986). It yields about 15,000 seeds per kg. Germination is 40 percent, if seeds are not attacked by insects. Seeds are germinated in receptacles after soaking in water for 24 hours.

Leaves and pods of jangli babul' are fed to sheep, goats and camels. Foliage yield of 100 kg per tree has been recorded in Rajasthan at Central Arid Zone Research Institute, Jodhpur, India. It has a high calorific value. Its timber is used for fence posts, agricultural implements and building materials. It is extremely valued for sand dune stabilization, as wind breaks and for planting in the desert and arid lands of Pakistan. Highly eroded areas in Pothwar Plateau have also been planted to this species (Mohammad et al., 1985). In trials at CAZRI, Jodhpur, *Acacia tortilis* grew twice as fast as indigenous acacias and that the plant withstood arid conditions better than *Acacia nilotica*, *Acacia senegal* and the local *Prosopis species* (NAS, 1983). No insects or diseases in Pakistan attack the tree (Sheikh, 1986).

Albizia Lebbek (Siris): Family: Leguminosae; Common name: Siris'. It is a large deciduous tree, with dark-grey irregularly cracked bark. It produces a spreading umbrella of feathery foliage. It may reach 30 m in height and a diameter of 1 m. It produces whitish, very fragrant flowers in pedunculate heads with striking green stamens. Pods 15-30 x 2.5-5 cm are flat and rounded on both ends (Khan, 1965).

Siris' is one of the best known trees in Pakistan, India, Bangladesh, Nepal and Burma. It is also cultivated in North Africa, the West Indies and South America. There are extensive plantations in Nepal and in Central and South India (NAS, 1983). It grows to an altitude of 1200 m in Pakistan and is cultivated everywhere in the plains. Its pods are conspicuous during most of the year because they hang on the tree long after they are ripe and throughout the hot weather when the tree is bare of leaves. When rattled by the hot winds, the pods sound like frying fish; hence, the tree is known in West Indies as the Fry Wood (Khan, 1965).

Siris' grow very fast but young plants are frequently killed by frost. It is frequently grown in the dry region on a variety of soils. Seedlings do not tolerate heavy shade and suppression and are drought and frost tender (Khan, 1965). It prefers moist conditions and grows best in well-drained loam soils. The trees tolerate salt spray and grow near the seashore (NAS, 1983). It is a prolific seed producer and is easily propagated by seed, even by direct sowing. Seeds remain viable for 4 to 5 years at ambient temperatures. It can also be propagated by stem cuttings or root-shoot cuttings. The root suckers sprout vigorously when roots are injured, (NAS, 1983). The growth of the tree during first year is exceedingly rapid. In Sukkur, a girth of 1.5-1.82 m was measured at 17 years (Khan, 1965). It produces 1-3 rings per 2.54 cm radius. Troup (1921) reports 3-4 rings per 2.54 cm. It can grow on calcareous as well as saline soils and has coppices well (Khan,

1965). Before sowing, seed should be immersed in boiling water and allowed to cool and soak for 24 hours. Germination is 50-90 percent (NAS, 1983). Misra and Singh (1981) found that seed scarification with concentrated sulphuric acid increased germination by 50 percent. Muthana et al., (1976) reported that transplanting 9-12 month-old seedlings increased survival and average tree height than direct sowing after 12 years.

Seedlings need to be regularly weeded during the first 2 years because they can be destroyed by browsing animals. The tree does not withstand wind as its roots are close to the surface. It is planted on avenues and to control erosion. In India, in a region receiving 400 mm of rainfall, siris' was successfully established in shifting sand dunes and in a shallow soil, 22.5 cm deep overlying hard calcareous pans (Kaul and Chand, 1979).

Young foliage of siris' contains 20 percent protein and is fed to livestock. One tree, may provide 20 percent of a buffalo's annual feed or 27 percent of the feed required by a cow (NAS, 1983). It is reported to be a well-known leguminous fodder tree with very palatable leaves (Negi, 1977). Chemical composition (percent of dry matter) and digestibility of its leaves has been rated by Prinsen (1986) as excellent. He reported that Indian siris' has potential in Queensland, Australia. It produces many leaves, which are shed during winter. Wood of siris' is dense (specific gravity, 0.55-0.6) and a good fuel. The calorific value of moisture free heartwood is excellent. Wood is also used for agricultural implements.

Artocarpus Integrifolia (Kathal): Family: Moraceae. Common name: Kathal'. It is a large evergreen tree with dense crown. It has dark brown bark and long, smooth leathery leaves. Fruits are long with a rough surface of conical tubercles. Other species are *A. chaplasha* and *A. lakoocha*, which are deciduous. Lakooch have small fruits, which are not tubercle. All the three species are found in northern Pakistan, India, Nepal and Bangladesh. They are propagated by fresh, perishable seed. The species are fast although growing seedlings grow slowly. The fruits are eaten by wild mammals and birds and are heavily lopped for fodder.

Bauhinia Variegata (Kachnar): Family: Leguminosae; Local name: Kachnar'. It is a medium-sized deciduous tree with a spreading crown and reaches a height of 10 m and a diameter of 50 cm. Bark is grey. Young shoots are brown and pubescent. Leaves are 10-15 cm long. Flowers are large, white or purplish and appear when the tree is leafless. Pods are 6-12 2-3 cm long, hard and flat with 10-15 seeds. The tree is leafless for a couple of months during winter. Flowering takes place during spring (Khan, 1965).

Kachnar' grows in Pothwar Plateau and in the Himalayan foothills up to an altitude of 1500 m. It is also widespread in northern India and in the Terai areas of Nepal. The annual rainfall requirement is from 500 to 2500 mm with extreme temperatures (maximum 40-47°C and minimum below zero). It grows on a wide variety of soils; from gravelly soils on mountain

slopes to sandy loam soils in the valleys and plains.

Kachnar' can be reproduced from seeds. Natural regeneration is also common in eroded areas in the Pothwar Plateau. Nursery raised seedlings spaced a 3 m intervals can be planted during monsoon in pits. Seedlings are adversely affected when roots are disturbed. It is usually grown in cultivated areas. No compact plantations are found in Pakistan. It is also planted in cities as an ornamental tree.

Leaves, flowers and fruits are eaten by goats, sheep and cattle. Average annual fodder yield per mature tree is 15-20 kg dry matter (Parkash and Hocking, 1986). Its fruits and flowers are cooked for human food, and have a high calorific value. The timber is used for agricultural implements. The bark contains tannins. Its decoction is used for diarrhea control and as an astringent and tonic. Seeds contain 16.5 percent of a pale yellow fatty oil (Parkash and Hocking, 1986).

Celtis Australis (Tagho) : Family: Urticaceae; Common name: Tagho', Kharik'. It is a middle-sized deciduous tree that attains a height of 9-15 m. Bark is bluish-grey or brown, often with whitish streaks. Leaves are ovate sharply and coarsely serrate. It is found in the Sulaiman range, Trans-Indus, Salt- Range and Himalayas, at altitudes up to 2500 m from Indus to Bhutan. It is also found in Afghanistan, western Asia and the mediterranean regions. It has been frequently planted in Punjab, N.W. Himalaya and in Sind and Baluchistan. Natural plants are common in Swat, Murree, Abbottabad and Neelam Valley. Tagho flowers in March to May, before leaves appear or with first the leaves. Fruits appear from July to September. Its trunk is short and straight and grows quickly (Khan, 1965). The tree is often planted to provide cattle and goat fodder. It is also cultivated for oars and tool handles.

Elaeagnus Angustifolia (Russian Olive): Family: Elaeagnaceae; Common name: Russian olive'. It is a medium-sized deciduous tree whose leaves drop late. Leaves are greyish on the upper surface with scattered scales and the free portion of the perianth tube is campanulate (Khan, 1965).

Russian olive is native to southern Europe, western and central Asia and the Himalayas. In Pakistan, it is extensively cultivated in the northern areas and Baluchistan. It requires considerable sunlight and can withstand poor soils but is not suited to water-logged areas. It grows up to 3000 m. For propagation, 1-2 year-old rooted plants, produced in nurseries, are used. Cuttings are also planted. Recommended spacing is 2.15 x 2.15 m. Irrigation is needed for first 4 years of establishment. It is used for timber. Leaves are used as hay for winter feed. Fruit berries are edible. Bark is used for tannin.

Grewia Optiva (Grewia): Family: Tiliaceae. Synonym: *G. oppositifolia*; Common names: Grewia', Dhaman', Bihul'. It is a medium-sized

tree with a spreading crown that reaches a height of 12 m and about 30 cm in diameter. It is semi-deciduous and flowers during spring; its fruits ripen in early fall. The tree is common in the Himalayan mountains of Pakistan, India and Nepal. It occurs at altitudes between 100 and 2000 m. It grows in sub-tropical humid zones where temperatures are relatively low and annual rainfall is from 1200 to 2500 mm. It can grow on a variety of soil types. However, sandy loam with adequate moisture is more favourable for its growth. It is fairly drought resistant and tolerant to frost.

Natural reproduction in *grewia*' is rare and the tree is propagated by direct sowing of nursery raised seedlings in containers during the monsoon. It is not grown as a regular forest tree but is mostly cultivated along agricultural fields.

Leaves of *grewia*' are very palatable and the trees are heavily lopped during winter when there is a shortage of green fodder in the hills. Its leaves are as nutritious as berseem, alfalfa or cowpea (Singh, 1982). Foliage yields up to 30 kgs/tree can be obtained from 2-year-old plants; leaf fodder yields as much as 11 t/ha were reported by Singh (1982). However the wood is not usually burned because it has an unpleasant odour. However, it is hard and heavy (800 kg/m³) and good for agricultural implements (NAS, 1977). The inner bark is used for rope making. The wood can be used for pulp and paper.

Leucaena Leucocephala (Ipil-ipil): Family: Leguminosae; Common name: Ipil-ipil: It is either a tall tree or a many branched shrub. It is semi-evergreen with feathery leaves, white flowers and large bunches of pods. It is indigenous to Central America and has been introduced widely in many tropical countries such as Australia, Philippines, Indonesia, Pakistan and India. There are more than 100 varieties of this species (NAS, 1977). In Pakistan K-8', K-28' are extensively planted in the Pothwar scrub ranges, along highways in Punjab and under dry conditions at Dhabeji, Sind. It requires considerable rainfall (600 - 1700 mm) but with irrigation it has been successfully planted in low rainfall areas of Sind receiving less than 300 mm of rainfall. With irrigation, the plants can be established in very dry areas. It can survive in high temperatures (45°C) and is found at altitudes up to 1000 m, grows well in neutral to slightly alkaline soils (pH up to 8) and is frost tender.

Ipil-ipil can be propagated by seed and coppice. Coppice growth is faster than that of seedlings. Its seed is broadcast in raised beds or in containers. Seedlings are planted during spring or summer rains. In a fuel-wood plantation, a 2-3-year rotation is maintained. Shrubby plants are cut back to a height of 1 m for fodder production. By cutting close to the ground every 5 years it has remained in vigorous conditions for 55 years in the Philippines (NAS, 1977). At a spacing of 3 m it can contribute about 100 kg N/ha/year to the soil.

Because of its many uses, Ipil-ipil is known as a magic tree. Dry matter yield of 25-30 t/ha/year can be obtained by planting at 1 m spacing.

Leaves and pods are very nutritious. It is used for charcoal production. The timber is used for agricultural implements.

Morus Alba. (Mulberry): Family: Moraceae, Common name: Mulberry', Tut'. It is a medium-sized deciduous tree, which is both wild and cultivated. Teeth of leaves are uniform and usually blunt. The perianth of female flowers has four segments, which are glabrous or shortly ciliate. Fruits are ovoid, white or nearly dark red when not fully ripe (Khan, 1965).

Mulberry is native to China, central Asia and Himalayan region. Large irrigated plantations have been established in Pakistan, in newly reclaimed and cultivated areas in the Northern mountains and Baluchistan. It grows up to 3200 m. It is shade tolerant and a fast-growing species, usually planted as a under-storey in plantations. The tree can be easily established either from seeds or from cuttings. It coppices well. It is grown on shorter rotations of 16-20 years. For fodder and firewood, a spacing of 2.15 x 2.15 m is recommended (AKRSP, 1987).

Mulberry leaves yield a good quality fodder, which are dried for hay and fed to livestock during winter. Its fruit is dried and used as livestock feed and leaves are used for feeding silkworms. Its wood is used for furniture and sporting goods but it is not a good firewood. Wood yield from a 8-10 year coppice rotation is 7-10 m³ /ha annually (AKRSP, 1987).

Olea Ferruginea (Kau): Family Oleaceae; Common name: Kau: It is



Plate 17. Ipil-ipil (*Leucaena leucocephala*) known for nutritious leaves and pods.

a medium-sized evergreen tree with grey bark. Leaves are 5-10 cm long, 1.27-2.54 cm wide and oblong. Flowers are whitish and bisexual.

Fruit is ovoid and 0.50 cm long (Khan, 1965). It grows in the foot hills of Himalayas, Pothwar scrub ranges, Kala Chitta hills, Sulaiman mountain ranges and in the Quetta-Pishin districts. It grows in association with *Acacia modesta* at altitudes between 500 to 2000 m with annual rainfall of about 500-1200 mm and prefers limestone rocky soils. The best growth is obtained on deep soils with sufficient supply of moisture (Singh, 1982). It is fairly drought resistant but susceptible to waterlogging and frost. It is propagated by direct sowing, rooted cuttings and root suckers. Its seed requires pre-sowing treatment of caustic soda or sulphuric acid to soften its hard endocarp. The leaves are valued as a nutritive fodder for cattle and they are believed to increase milk production.

Populus Spp. (Poplar): Family: Salicaceae, Common name: Poplar'.

It is a medium-sized fast growing deciduous, single bole tree which reaches a height of 10 m. Bark is white, leaves are broadly ovate and green, and turn yellow before fall. New leaves appear in March. The Poplar' species present in the northern areas are *Populus nigra*, *P. alba*, *P. deltoides*, *P. euramericana* (hybrid poplar) *P. euphratica* and *P. ciliata*. The associated vegetation includes *Aesculus indica*, *Prunus padus* and *Cedrela serrata*.

Most of the poplars are native to Europe, China and the Himalayan region, including Pakistan, India, Nepal and Bhutan. These are also extensively cultivated in the irrigated plains of Punjab and NWFP and can grow up to 3200 m. The trees are mostly planted along water channels. For block plantation 2.15 x 2.15 m spacing is recommended. It can be propagated by cuttings made from 1-year-old wood preferably from stool or pollards (AKRSP, 1987). It is planted during the spring or summer rainfall seasons. Propagation of *P. alba* by suckers is more successful. Nutrient requirements are moderate but it can exhaust poor soil.

Poplars have moderate value as a fodder. Leaves are used for winter livestock feeding in the northern areas. Firewood quality is poor. Timber is high, soft and easily worked. It is used for furniture, packing material, matches and poles.

Prosopis Juliflora (Mesquite): Family: Leguminosae; Common name: Mesquite. This thorny semi-deciduous, large-crowned and deep rooted tree may grow to 10 m or more depending on the variety and site. The leaves are dark green. Leaflets (10-15 pairs) have mid-ribs near the centre. The long fleshy pods are straw-coloured when ripe. Flowers are pale cream-coloured in auxiliary spikes. It can grow upto 1500 m above sea level and thrives where annual rainfall is 200 mm (Sheikh, 1986). The species is native to Central and South America. The other species of mesquite is *P. glandulosa*. The tree has been planted in many arid zones of the world. It is widely propagated in Africa and Asia, particularly in India (NAS, 1983). It was introduced in Pakistan in early fifties, mainly for to stabilize dunes

and for fuelwood. Excellent plantation research has concerned its ability to stabilize sand dunes in Pasni and Gwadar in Baluchistan. The tree grows on a variety of soils but does well on sandy soils and can grow on rocky terrain provided its roots do not face competition.

Mesquite grows fast on a 15-year rotation with an expected yield of 75-100 t/ha which may be 50-60 t/ha with a 10-year rotation (Sheikh, 1986). It is reproduced easily by root-suckers and seed. The tree coppices readily. To overcome seed-coat dormancy, its seed must be mechanically scarified and either treated with 20 percent sulphuric acid for 1 hour or soaked in concentrated sulphuric acid in about 20 minutes, or covered with boiling water and allowed to cool and soaked for 24 hours in water (Sheikh, 1986). It is an aggressive invader and is a nuisance in irrigated plantations. This is a species to be tried only in very arid problem sites; elsewhere, may cause severe problems (NAS, 1983).

Mesquite wood is hard and heavy with a specific gravity of 0.70 or higher and is excellent for firewood and makes superior charcoal. Because of its high caloric value, the wood has been termed "wooden anthracite". It burns slowly and evenly and holds heat well (Sheikh, 1986). The tree is also valued for shade, timber and forage. The pods are eaten by livestock and may also be ground into flour for human consumption. It is planted where other more valuable forest species cannot be grown (NAS, 1983).

Prosopis Cineraria (Jand): Synonym: *P. specigera*; Family: Leguminosae; Local name: Jand, Kandi. It is a medium-sized thorny tree, 10-18 m high and about 60 cm diameter, with an open crown. It is leafless for a short period before flowering. Creamy white flowers appear in spring while leaves are light green. It grows in the tropical desert rangelands of Thal, Cholistan, Tharparkar, Kohistan and in the lowlands of Baluchistan and Pothwar Plateau. Scattered trees are also found in cultivated areas, along roads, canals and railway tracks (Mohammad, 1984). In India, it occurs in the arid lands of Rajasthan, Haryana, Punjab and the southern states. It also occurs in Iran, Afghanistan and Arabia (NAS, 1983). In Pakistan, it is associated with *Acacia nilotica*, *Salvadora oleoides*, *Zizyphus mauritiana* and *Calligonum polygonoides*. It requires 75 to 850 mm of moisture and tolerates high temperatures up to 50°C. Sheikh (1986) reports that jand' is found throughout the plains of Punjab and Sind in areas receiving less than 300 mm of rainfall. He further reports that in wild lands, 'jand' usually attains the girth of 1 m with an average height of 7-8 m. Jand' is a tropical tree growing in a wide range of soils with sufficient sub-soil moisture. It is drought, salt tolerant, and tolerates pHs as high as 9.8.

Propagation of Jand' is done by seed, root suckers and coppice. The seeds remain viable for 2 years, germinate after 10 days of sowing (Sheikh, 1986). Two to 3-year-old seedlings raised in polythene bags are planted during monsoon. Natural regeneration by seed is confined to moist depressions and along river and stream channels. Direct sowing of jand' in mixture with *Cenchrus ciliaris* has also been successful in Thal ranges at Dagar

Kotli (Mohammad, 1987). Since very few pure stands of jand' are maintained in Pakistan, no specific silvicultural system has been prescribed. In India, clear felling when trees are 30-40 years old is followed by coppice regeneration (Parkash and Hocking, 1986).

The tree is lopped for pods and fodder. Leaves and pods are browsed by goats, sheep, cattle and camels. Foliage yield data are not available in Pakistan. However, dry matter yield of 60 kg from leaves and pods per tree has been reported in India by Singh (1982).

Srivastava (1978) reported that annual lopping of trees results in maximum forage yield without detrimental effects on growth. It has also been observed that yield of forage from trees having girth less than 45 cm is lower, thereby suggesting a lower girth limit when trees should be lopped. Complete lopping significantly decreases leaf fodder yield compared to lopping two-thirds and one-third of the crown (Bhimaya et al., 1964). There is a substantial decrease in the forage yield as a result of recurrent lopping and trees should be given some rest between successive loppings to sustain forage yield (Srivastava, 1978). Its wood is an excellent fuel. Sheikh (1986) reported that the expansion of canal irrigation in the desert areas, is associated with a gradual disappearance of the tree as it is a good firewood and makes fine charcoal. Its timber is very strong and hard and durable and is used in construction, agricultural implements, tool handles and shafts (Parkash and Hocking, 1986).

Quercus Leucotrichophora (Banoak): Synonym *Q. incana*; Family: Fagaceae; Local name: Banoak. This medium-sized evergreen broad-leaved tree attains a height of about 10 to 15 m and a diameter of 60 cm. Leaves are 6-15 cm long, oblong or ovate lanceolate acuminate, sharply serrate, and dull green. Bark is grey to greyish brown, and is longitudinally and transversely cracked.

Banoak' is a common climax tree of the moist temperate and subtropical humid forests in the Himalayas. It occurs at altitudes between 1300 to 2600 m, with annual rainfall of 1000-1800 mm and moderate temperatures. It grows on a variety of geological formations, including shale, gneiss, mica schist, quartzite and limestone. It is frequently found on clayey soil. It usually grows gregariously on all aspects but attains its largest dimensions on cool northerly aspects with deep moist soil. The associated vegetation of 'banoak' includes *Cedrus deodara*, *Pinus wallichiana*, *Pinus roxburghii* and *Rhododendron sp.* of broad-leaved trees. Among its common companions are *Populus ciliata*, *Acer oblongum*, *Ulmus wallichiana*, *Alnus nepalensis*, etc. It is a very useful nurse tree to the deodar on hot slopes. Mixed forests of banoak' and chirpine are particularly common. It is sensitive to drought (Parkash and Hocking, 1986).

Banoak' is reproduced by seed, and coppice. Natural regeneration is possible if wildlife damage is prevented as acorns are relished by bears, monkeys, squirrels, rats and birds. Planting of 3-4-year-old nursery raised seedlings is quite successful during the monsoon. In Kangra (India), broad-

cast sowing after hoeing the soil without breaking the clods has also been successful (Parkash and Hocking, 1986). The silvicultural system followed for the management of the natural forests is coppice with standards (Singh, 1982). Establishment techniques for other species of the genera are similar. In Nepal, acorns are collected beneath the mature trees during October-November and sown immediately into a raised bed. These are pushed 1 cm into the soil with the point of the acorn facing upwards. The bed is then covered with a 1-2 cm layer of leaf litter or well-rotted compost. The seedlings are put into containers when the first leaves appear; then left to grow further for 18 months before planting out. The lopping of trees may not be allowed during plant establishment.

Oak trees are extensively lopped for fodder in all countries of the Himalayan region during the winter. Continuous lopping is harmful, so, rotational lopping on a 3-4 year cycle has been suggested by Parkash and Hocking (1986). A mature tree can yield about 20-25 kg of leaves annually. Banoak' is extensively cut for fuelwood (Parkash and Hocking, 1986). Timberwood is very hard and heavy and is used for construction, agricultural implements and furniture manufacturing. It contains useful tannins. Leaves provide material for rearing silkworm.

Robinia Pseudoacacia (Ain ul Asal): Family: Leguminosae; Common names: Robinia, Black locust. This short fast-growing deciduous tree has white and fragrant flowers that appear in April and fruit pods that mature in September-October. Leaves are 10-15 cm long; petioles are swollen at the base. Stipules become nearly straight or slightly curved with up to 2 cm long-leaflets, 9-20 opposite or sub-opposite. Flowers are white while pods are as long as 10 cm.

Robinia is indigenous to North America. In Pakistan, it has been planted in Tarbela and Mangla watersheds, in Kaghan and Neelam valleys and along the Karakorum highway. It grows well at altitudes between 1000 to 2000 m receiving 700 - 1500 mm annual rainfall in relatively cooler climate. It prefers well drained deep soils with adequate soil moisture and is capable of growing on soils with pH ranging from 4.6 to 8.2 (Singh, 1982).

Robinia is normally propagated through seed. Vegetative reproduction is also easy. About 8-10 month-old seedlings are planted out during the monsoon in pits. Naked root plants can also be planted (Singh, 1982) but it is preferred to have soil intact seedlings grown in polythene bags. No silvicultural system for this tree has been prescribed in Pakistan and India.

The leaves of robinia' are highly palatable. It is very useful for erosion control and coppices easily to form a protective hedge plant. It produces fuelwood of high quality. Timber is used for agricultural implements. The bark contains tannins. The tree has attractive flowers and is also grown as an ornamental plant along roadsides. It enriches the soil through nitrogen fixation. The tree is also used for shelterbelts and sand dune stabilization. In certain cases, roots, bark, sprouts, seed pods and

trimmings are reported to be poisonous for animals (NAS, 1983).

Salvadora Oleoides (Wan): Family: Salvadoraceae; Local name: Van, Pилоo. It is a shrub or small-sized tree with drooping branches, an evergreen, which reaches a height of 4 m. Flowers are yellow to greenish white and its sweet fruit ripens in June. It is a tropical shrub indigenous to India and Pakistan and is extensively found in Thal, D.G. Khan, Cholistan, Tharparkar and the Salt Range scrub ranges. It is a climax species of the Indus Plain. It is also found along railway tracks and abandoned fields. It is associated with *Prosopis cineraria*, *Capparis aphylla* and *Tamarix aphylla*. Wan' is a species of the desert, highly drought resistant and can grow in saline areas. It withstands extreme temperatures and can survive with little rainfall (180 mm). It occurs at altitudes up to 900 m and performs well on

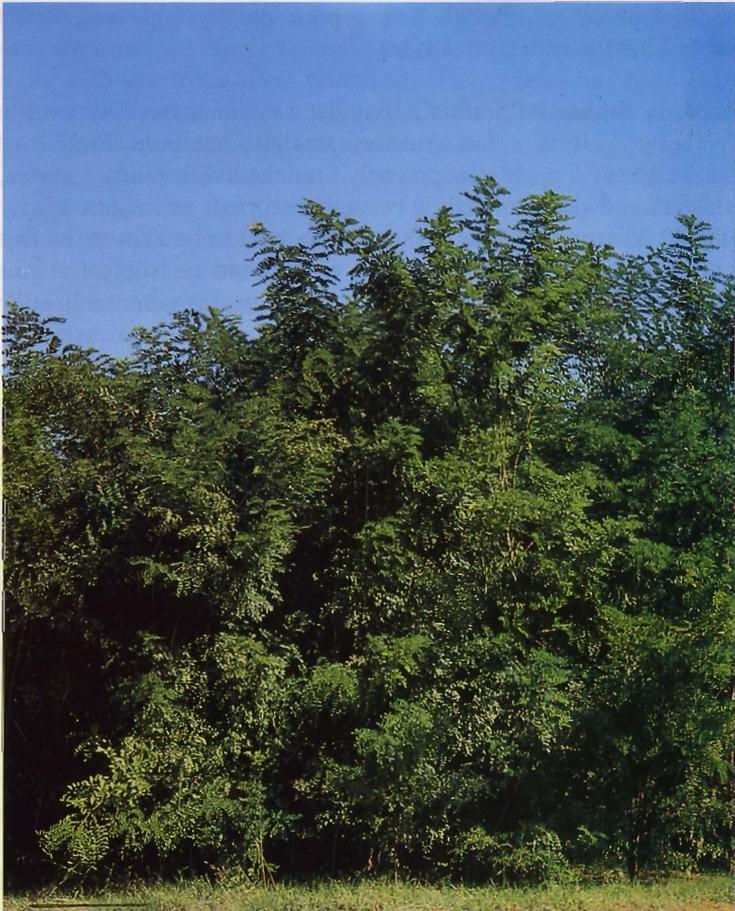


Plate 18. Black locust (*Robinia pseudoacacia*) planted for soil conservation and fodder in the Himalayas.

medium and fine textured soils such as sandy loam and sandy clay loams (Parkash and Hocking, 1986).

Wan' is reproduced through seed, coppice, root suckers and by natural layers. However, natural regeneration is not very successful where rainfall is low. During seedling establishment, tree shade and protection from livestock grazing is desirable. *Capparis aphylla* acts as a mother plant for the establishment of seedlings.

No research has been conducted on its establishment procedures in Pakistan. The trees are being replaced by *Cenchrus ciliaris* and fast-growing trees such as Acacias. In India, forests containing wan' are managed by the coppice with standard system on a coppice rotation of 40 years (Parkash and Hocking, 1986).

Wan' is browsed by camels, goats and cattle throughout the year. It provides good foliage during the winter and a mature tree can produce as much as 20 kg/year. Although it is a poor quality fuelwood, it is being uprooted in Thal for use in brick kilns.

Sesbania Sesban ('Sesban'): Family: Leguminosae; Common name: Sesban', Jantar'. It is a fast-growing, small to medium sized tree that reaches a height of 6 m. It is copiously branched with pinnate leaves, pale yellow flowers and slender, slightly twisted seed pods as long as 25 cm long, containing 20-30 seeds (NAS, 1983). It is reported to be among the first garden plants grown in Egypt. It is now widespread in tropical Africa and throughout tropical Asia. It has three varieties and is commonly cultivated in the Punjab and Peshawar areas (Khan, 1965). A stem growth of 5 m in 12 months has been reported and a yield of 75 t/ha (10 percent moisture) in 1 year was recorded in India (NAS, 1983).

Sesban' grows at altitudes of 300-500 m in Pakistan. In India, it is grown throughout the plains and up to an altitude of 1200 m. It requires 300-1000 mm rainfall. In Pakistan, the tree tolerates temperatures from 10°C to 45°C. It tolerates a wide range of soil conditions and withstands acid soils, periodic flooding and waterlogging. It can endure 0.4-1.0 percent salt concentration in the seedling stage and 0.9-1.4 percent near maturity (NAS, 1983).

Sesban' can be grown either by direct sowing or by raising seedlings in polythene bags and then planting the after 6 months. No pre-sowing treatment is required. However, the area under cultivation must be protected from cattle, because its forage is palatable and is subject to browsing. It has several uses. In Bihar, the flowers are eaten as a vegetable. The leaves are eaten in Thailand. The seeds, high in protein (33.7 percent), are eaten during famine in India. In Senegal, the stems are used for arrows and pipes. In India and Pakistan, stems are used as roofing for huts and the plant is cultivated as a substitute for bamboo. In India, Sesban is extensively planted as a windbreak and shade plant for vegetables, betel, vines, coffee, turmeric and cotton. In Pakistan, it is planted as an intercrop for soil improvement because it is usually rich in nitrogen. In India, it is often

grown as green manure in both dry and wet rice fields (NAS, 1983). It also provides a good fodder. Branches and leaves are fed to cattle.

Tamarix Aphylla (Frash): Synonym: *T. articulata*; Family: Tamaracaceae: Common names. Frash, Ghaz. This medium-sized, fast growing tree has an erect trunk and rough bark. Branches are articulate at the base of the sheath. Its leaves are sheathed and flowers are white during May-September (Khan, 1965).

Frash is native to the Indus plains in Sind, Punjab and tropical desert areas in India. It also grows in Afghanistan, Iran, Arabia and North Africa. It is a tree of the desert with high salt and drought resistance. It occurs as a pioneer species along river beds. It is associated with *Prosopis cineraria*, *Salvadora oleoides* and *Capparis aphylla*. It grows in areas receiving 350-500 mm rainfall and where temperatures vary from -5 to 50°C.

Frash can be reproduced from seed. Plants can be raised from seeds in polythene tubes. It coppices well. It is planted during the monsoon. For fuelwood, a 25-year rotation is practised. The species has been planted for sand dune stabilization in Mastung (Baluchistan). Roadside plantations are also found in Thal, near Peshawar and in Sind.

Frash is browsed by camels, goats and sheep. Timber is used for handicrafts, furniture and fruit boxes. It produces low quality firewood. The species provides excellent windbreaks in arid zones.

Zizyphus Mauritiana ('Ber'): Family: Rhamaceae; Common name: Ber'. It is a small to moderate-sized deciduous tree with a short bole, spreading crown and sweet fruits. It reaches a height of 10 m and a diameter of about 30 cm. The branches often droop and are armed with stipular spines. Leaves are velvety tomentose beneath and glabrous above. Flowers are greenish yellow, fruit a drupe yellow orange becomes red when mature (Khan, 1965). The old leaves fall after March-April and new leaves appear at the same time. Flowers appear from April to October and the fruit ripe from December to March (Sheikh, 1986).

Ber' is indigenous to Pakistan, India and Nepal. It grows at elevations up to 1800 m in Pakistan (Khan, 1965). It is a tree of tropical arid lands in the Indus plains and Baluchistan lowlands. It is associated with *Capparis decidua*, *Prosopis cineraria* and *Acacia nilotica*. It is highly drought resistant, needs little rainfall (125-500 mm) and can tolerate extreme temperatures in the range of -5 to 50°C. It can grow on a variety of soils but prefers deep sandy loam or slightly alkaline soil. Sheikh (1986) reported that ber' easily recovers from injury of any kind, including fire.

Ber' can be raised easily by direct seeding. Cultivated varieties are propagated by budding or grafting on to wild seedling rootstocks. Natural regeneration through coppice and root suckers is also quite successful and reliable (Parkash and Hocking, 1986). Normally, no seed treatment is needed for raising seedlings in the nursery. It is planted during spring, summer and monsoon seasons. It is readily browsed by goats and is a good

camel fodder. The branches and leaves are lopped for cattle fodder (Sheikh, 1986).

There are no large plantations of the tree in Pakistan. As soon as the tree starts growing it is lopped for fodder and very few young plants are allowed to mature (Sheikh, 1986). Ranjhan (1977) reported that ber' leaves are an important feed for goats and sheep in the arid lands of India and are more palatable than *Ficus religiosa* leaves. Young branches and leaves are lopped for cattle, goats and camels. Leaves are also used to feed silkworms. Bark contains tannin. The fruit is eaten fresh. The tree acts as a host for the lac insect. It is an excellent fuel with a high caloric value. Its timber is heavy and hard and is used for house building, agricultural implements, oil crushers, golf clubs, toys, tourney and pencils.

FORAGE LEGUMES

Legumes are an excellent source of feed for livestock. They also improve soil fertility by hosting nitrogen fixing bacteria. Potential of legumes as forages has not been fully explored in Pakistan. Promising forage legumes are being introduced in different ecological zones through the PARC sponsored National Forage and Pasture Programme. During the past 12 years, a few promising varieties of alfalfa, vetches, clovers, annual medics and cowpeas have been selected. A few important forage legumes are described below:

Medicago Sativa: (Lucerne or Alfalfa): This is an erect to sub-erect, widely grown herbaceous perennial legume. The plant is 30 to 60 cm high. The leaves are trifoliately pinnate and are arranged alternately on the stem. Leaflets are 3 to 10 mm broad. There are 5 to 25 or more stems per plant that arise from a woody crown, from which new stems grow when the older ones become mature or are cut. The inflorescence is a pedicellated raceme with various shades of purple, yellow and white flowers. The root is a distinct tap root system, which may penetrate into the soil up to 8.0 m. The fruit is a loose spiral of 2 - 4 turns, glabrous, with 10 - 20 kidney shaped seeds (Ali, 1977).

Cross pollination in lucerne is necessary to produce good quality seed. Harvesting is a critical problem because all the seed does not mature at the same time. Harvesting occurs when two-thirds of the flowers turn dark brown. The seed shatters readily, so the crop should be handled carefully.

Alfalfa has the highest feeding value and digestible protein of any forage. It has high mineral content and contains vitamins, especially vitamin A. For these qualities alfalfa is called "Queen of Forages" and is an excellent pasture for cattle. It generally intercropped with crops for pasture and hay. It is also improves the soil crop and is used in rotation for its beneficial effect on succeeding crops like wheat, barley and sorghum (Hughes et al., 1969).

Lucerne is found all over the world and is well adapted to a wide

range of ecological conditions and soil types. It is very well adapted to fertile soils in dry climates with adequate moisture. It is also adapted to humid climates with good fertilization and adequate cultural practices and is relatively tolerant of moderate alkalinity. However, it does not grow well on very alkaline soil. It also tolerates drought but becomes dormant during prolonged drought and resumes growth when more moisture is available.

Alfalfa is sown in the fall, preferably in October, at a seeding rate of 15 - 20 kg/ha. Seed should be about 1 cm deep in the soil. The crop should be cut at one tenth flowering stage. High quality hay is also produced at this stage. On the other hand, late cutting reduces the crude protein content. The number of cuttings per year varies from one in very dry areas to six under irrigated conditions. However, 3 - 4 cuttings is normal. Seed production of alfalfa has been a serious problem. For seed production, row spacing of 60 cm is better than broadcast.

Alfalfa is a major fodder crop of the irrigated belt. Alfalfa is produced under rainfed conditions in a limited area. In the Northern Areas, hay of alfalfa is used during the winter. It is also extensively cultivated in Quetta and Mastung valleys under irrigated conditions. The National Forage and Pasture Programme in collaboration with Utah State University and is testing 52 improved varieties of alfalfa from the United States and Canada along with eight Pakistani varieties at Khawar Mong, Jaglote, Islamabad and Mastung areas to select suitable varieties for different ecological conditions.

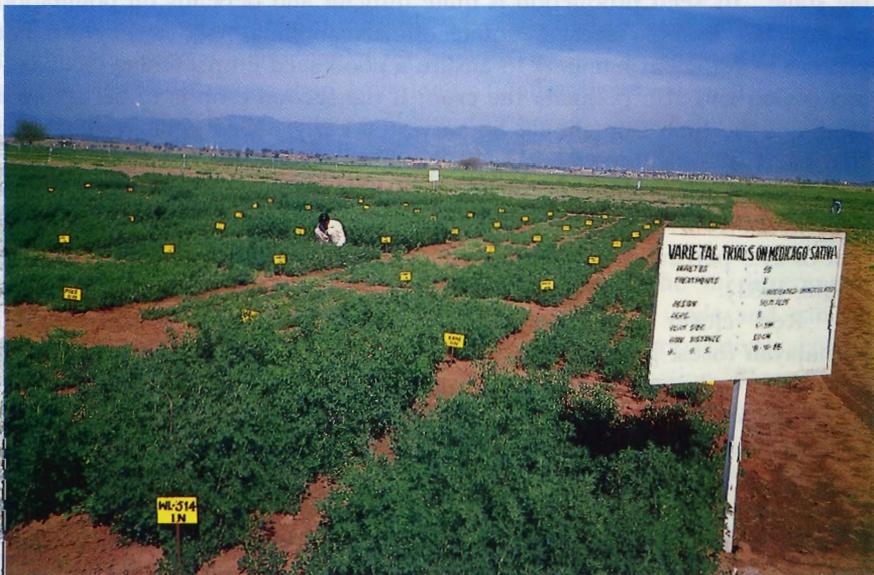


Plate 19. Lucerne (*Medicago sativa*) adaptation trials at National Agricultural Research Centre, Islamabad.

Trifolium Pratense (Red clover): It is erect to decumbent perennial herbaceous plant. Leaves are trifoliate and leaflets are 1.5 - 30 cm long with a characteristic light coloured marking in the centre of each; leaves are obovate to broadly elliptic and stipules are ovate-lanceolate. Purple flowers are borne on compact clusters at the tip of the branches. The number of flowers per head is highly variable. Pods are single seeded, short and break open transversely (Ali, 1977).

Red clover is widely distributed all over the world and is an important forage crop in Central Asia, Europe, New Zealand, Australia, the United States and Canada. Fertile, well-drained soils with relatively high water holding capacity are most suited for red clover. It prefers moderate summer temperatures and adequate moisture throughout the growing season. Its tap root system is branched and most of the roots are concentrated in the top 30 cm of the soil. However, it does not resist to drought. It can grow on moderately acidic soils but shows best growth at a soil depth of pH 6 provided adequate calcium is available. The nitrogen fixation ability of red clover is enhanced with proper inoculation. With high levels of soil fertility and plentiful supply of calcium and phosphorus, it becomes the most effective legume in the fixation of nitrogen from the air.

Red clover is grown in the spring at a seed rate of 8 - 10 kg/ha. When grown in mixture with a grass, 4 - 6 kg/ha is the usual seeding rate. For first year, clipping should be done in late summer to avoid weed competition and damage by mice. Red clover should be cut for hay slightly before or at full maturity. Best results are obtained by harvesting the crop at half flowering stage. Its seed production is quite difficult and depends on pollination by insects. Bumble bees are quite effective pollinators but they are not present in sufficient numbers to ensure a good seed crop. Honey bees collect pollen and also pollinate the crop. If the second crop is to be used for seed, of the first crop should be harvested early. Seed is harvested when stems are yellowish brown and heads have turned brown.

Red clover is valuable for hay, pasture and soil improvement. It sustains yields for 4 - 5 years (Hughes et al., 1969). It has a crude protein content of 21.5 percent at the pre-bloom stage; hay contains 9.8 percent protein (Gohl, 1981).

Red clover has been introduced in the Trans-Himalayan and Himalayan forest grazinglands. Noor (1981) tested red clover at Jaba. It has also been sown at Kalam, Swat valley, the Northern Areas, Neelam Valley and near Murree. Annual forage yield at Jaba, Kalam, Jaglote, Khawar-mong, Islamabad and Peshawar was 4.2, 3.5, 4.3, 5.2, 4.1 and 4.5 t/ha, respectively.

Trifolium Repens (White clover): This is perennial, prostrate, herbaceous plant roots at the nodes. Leaves are composed of three sessile leaflets which may be broadly elliptic to obovate rounded at the apex. The petiole of the leaf is long and the stipule broad at the base and sheathing. The flower heads are on relatively long stalks composed of a globose

raceme, borne in the leaf axils at the nodes of the stems. These are 15 - 25 mm broad containing 40 - 100 flowers. They are normally white but may have a pinkish tinge. The seed pod of a single floret may contain 1 to 7 seeds. The florets are mostly self-sterile and must be cross-pollinated for seed setting. The seed matures in 23 - 28 days. It is very small and 1 kg seed may contain 1.5 million or more seed. Seed is bright yellow and round with a hard seed coat (Ali, 1977).

White clover is native to Europe. It probably originated in the eastern mediterranean countries or in West Asia. Now, it is one of the most widely distributed legume throughout the world. The small seed, the hard seed coat, the long period of flowering, high palatability and seed dispersal by birds are the factors enhancing seed dissemination. Generally, white clover is best adapted to the clay and silt soils in a humid climate. It can also be successfully grown on sandy soils with relatively high water table and in areas where mineral fertilizers are applied.

White clover is a very important pasture legume, due to its high nutritional value and palatability, it is liked by all classes of livestock. When intercropped with grasses, it increases the production and protein content of the herbage. White clover is widely used for hay and silage when grown in mixture with other legumes and grasses. It also makes a good cover crop in orchards (Hughes et al., 1969).

Environmental requirements of white clover are similar to those of red clover. Forage yield at Jaba, Kalam, Jaglote, Khawar mong, Islamabad and Peshawar was 3.5, 3.1, 3.6, 4.2, 4.1 and 3.7 t/ha, respectively.

Vicia Sativa (Common vetch): This semi-viney annual herb has a decumbent, erect or climbing plant body. The leaves are pinnately compound with petioles less than 1 cm long. Leaflets are 1 - 4 cm long, 2 - 15 mm broad, linear to lanceolate, oblong to obovate. Stipules are 3 - 8 mm long and tendrils are generally branched. There are usually 1-2 flowers, rarely 3, which are auxiliary, sessile, or shortly pedicellate and violet or purple. The fruit is 2.3 - 6.5 cm long, 4 - 8.5 mm broad, narrowly oblong and contains 6-12 seeds (Ali, 1977).

Common vetch is native to Europe, Asia and the mediterranean region. It is best adapted to well-drained fertile loam soils and can be grown on sandy soils if well fertilized. It requires comparatively cooler season to develop a good stand, especially for seed production. However, it is less winter hardy than the other vetches and often suffers winter damage.

Common vetch seed is sown during October at 40 kg/ha. Inoculation of seeds improves results. Seed must be carefully harvested because seed shatters readily. Thus, it should be harvested when the lower pods turn brown. Cutting at night, early morning or a cloudy day reduces seed losses. The crop is cut with a mower and is threshed when dry. Common vetch is used as a cover crop to help protect the soil from erosion. By adding organic matter, it improves the physical condition of the soil when grown as a green manure crop. It is palatable to livestock. Early maturity, long

periods of bloom and more cuttings make it suitable as a forage crop. Reseeding and by deferring grazing, will maintain a good stand. It is also intercropped with a number of grasses, e.g., oats, to increase forage yield and crude protein content. It can also be used as hay (Hughes et al., 1969).