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RESEARCH ON FOURWING SALTBUSH IN HIGHLAND BALOCHISTAN

A STATUS PAPER

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LIST of Collaborating Scientists

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1. Introduction

1.1. Area, Climate and Vegetation:

Balochistan is situated in the south western part of Pakistan in a desert belt between 25° N and 32° N. With an area of about 34 million ha and population of about 5 million, Balochistan is the largest and most sparsely populated province of Pakistan. Highland Balochistan is generally defined as those areas above 1000 m altitude. Highland Balochistan has many flat valley bottoms surrounded by sloping rangelands that merge into mountains. The valley bottoms lie between 1000 and 2200 m altitude and the mountain peaks reach 3600 m. (Thomson and Rafique, 1992).

Balochistan has an arid or semi arid climate with annual precipitation varying from 50 mm in the west of over 400 mm in the east. The rainfall distribution pattern is erratic with extremely low and high temperatures (Kidd et al. 1988). Physically the area consists of an extensive plateau of rough terrain divided into basins by mountains. Balochistan has been divided into two major crop ecological zones by Rafiq (1976). Most of Balochistan south of 30° N has been classified as hot subtropical desert, where the rainfall varies from 50-150 mm and the principal landuse is grazing with some agriculture. Whereas the high altitude areas of northern and eastern (highland) Balochistan with an altitude of 1000 m to over 3000 m are climatically classified as semi arid continental Mediterranean (Rees et al. 1988). The climate of highland Balochistan is harsh, with annual rainfall increasing from 200 mm at the southern end of the highlands to over 400 mm in the north-east of the province. Rainfall occurs both in winter and summer, with winter rains are predominant in the north west which is less affected by monsoons. Summers are hot in subtropical desert and mild in highland areas. Winters are cold with mean minimum temperatures in January close to zero, although absolute minimum temperatures can fall to -15°C.

The vegetation of the northern highland area is a grassland type on the lower range where annual precipitation is 300 mm, with 40% occurring in summer and mixed grass-shrubland in the higher rangelands with *Chrysopogon aucheri* and *Cymbopogon jwarancusa* being the major grass species. While in the southern part of highland Balochistan, the vegetation can be classified as an *Artemisia* and *Haloxylon* shrub steppe (Hasnain 1985), where the annual precipitation is 200 mm, with 80% occurring during winter.

1.2. Distribution and Description of Fourwing Saltbush:

Atriplex canescens commonly known as Fourwing saltbush is an exotic halophyte and occurs from the West-central Great Plains to the Coastal Range of United States and from northern Mexico to canada. It is an evergreen shrub with dense foliage, about 1.8-2.7

m high and 2.4-3.6 m wide. The leaves are grey green, 1.5-5 cm long, 2-8 mm wide, linear alternate, elliptical or spatula shaped, covered by dense grey scales on both surfaces, directly attached to stems. It bears staminate or pistillate flowers which born on separate plants. Male flowers are found in dense spikes forming long terminal panicles, while female flowers are found in dense leafy spike-like panicles. The flowering period is from July through August. Seed is enclosed in bracts and matures through the fall months. Bracts are directly attached, forming four projected fringed wings united in a thick body over the seed, approximately 6-15 mm long and 4-8 mm wide (USDA, SCS, CAES and CDFG, 1979).

1.3. Ecological Adaptation:

Most saltbush species including fourwing saltbush are adapted to arid or semi-arid mediterranean and/or subtropical climates located between 20 and 50° of latitude North and South in Eurasia, Africa, North and South America and Australia (Francelet and Le Houerou, 1971). Fourwing saltbush is an exotic halophyte shrub with dense foliage and extensive root system and is adapted to wide range of soils and climates. It thrives in areas where the mean annual precipitation is as low as 250 mm. It can develop under cultivation in the arid zone between the 200 and 400 mm isohyets of mean annual rainfall, under strictly rainfed conditions (Le Houerou, 1992). In areas, where mean annual rainfall drops below 200-250 mm, additional water from runoff, or irrigation, or the presence of a water table is mandatory for good production. Fourwing saltbush shows a high adaptation to cold environments, withstanding -20° C and below in some parts of Western United States. On the other hand, It shows "Kranz" leaf anatomy and therefore exhibits C4 carboxylation pathway of which the optimum temperature for photosynthesis is high (30-35° C) which enables it to survive during hot dry periods in arid climates. *Atriplex canescens* is adapted to sandy soils but shows the best development and highest productivity on medium textured deep soils (Le Houerou, 1992). It is also reported to do better on more shallow silty soils e.g. soils having shallow lime crusts etc. Fourwing saltbush is categorized as Meso-euhalophyte, which is considered to be a good tolerant of saline conditions. Although it can be effectively grown on saline soils, but performs well in non-saline soils with alkaline soil reaction.

1.4. Biomass and Productivity:

The biomass and productivity of fourwing saltbush is highly variable, depending upon the ecological condition of the soil and climate as well as the management applied. Artificial plantations of fourwing saltbush under rainfed conditions, can yield upto 2000-4000 kg dry matter/ha/year in areas with mean annual rainfall of 200-400 mm under proper management (Le Houreou, 1992). Fodder production from *Atriplex* plantations may thus reach 3-6 time as

much as fair condition rangelands and constitute a buffer forage reserve for drought periods or periods of regular scarcity such as late summer and autumn. The ratio between forage and wood in *Atriplex* species is about 50% which can be improved by appropriate management like pruning etc. (Le Houreou, 1986). Atriplex canescens react strongly by a profuse rejuvenation after cutting back or pruning. Young leaves and twigs show a much better forage quality, with a higher nitrogen content and a lower amount of ashes and salts. In rejuvenated stands, the leaf/stem ratio may be of the order of 70-80% until approximately 6 months and then slowly decreases (Le Houreou, 1986). For a sustained biomass production, cutting back should occur for fourwing saltbush every 2nd to 3rd year depending upon the management and grazing intensity.

1.5. Forage/feed value of fourwing saltbush

The most desirable characteristics of fourwing saltbush include its extreme drought and cold tolerance and high quality browse especially during summer and autumn months. This shrub is a perennial halophyte which continues to produce leaves and twigs round the year. The crude protein content of leaves of Western Texas ecotypes of fourwing saltbush have been reported in the range of 16-18 % during mid winter (J.L. Petersen and D.N. Ueckert, unpublished data). It has been suggested that i acre of fourwing saltbush might provide the supplemental protein requirements for 0.5 to 1 animal unit during a 90-day period (Ueckert, 1985). Like other halophytes, fourwing saltbush has low energy values because of high ash contents. The energy values are reported to cover only maintenance requirements of sheep if they consume 1.2-1.5 kg DM/d (Le Houerou, 1992). But nutritionally, saltbush species contain high nitrogen values which have been reported to be as high as 2.5-3.5 % DM , i.e., 16-20% of crude protein (Le Houerou et al., 1982, 1983; Hassan et al., 1979). The digestibility of dry matter and of organic matter has been reported to be around 60% and 50% respectively (Le Houerou et al., 1983). The digestibility of nitrogen has been reported to be around 65% but the retention of nitrogen is only 55% (Benjamin et al., 1991). Atriplex supplemented with grazing of native ranges resulted in animal weight gains of around 80 g/h/d (Le Houerou et al., 1983). Atriplex forage consumption in addition to stubble or wheat straw consumption could lead to a well balanced ration and fulfil the nutritional requirements of animals in a productive grazing system (Le Houerou et al., 1991).

1.6. Role of AZRI in Fourwing Saltbush Research:

Fourwing saltbush was first introduced in Mediterranean Balochistan highlands in mid 50's at Maslakh Range, some 40 km west of Quetta with funding from USAID. Subsequently, the shrub was grown at Mastung farm by Soil Conservation Department. during early 1960's by Balochistan Forest Department. Nursery raised seedlings

were planted in few demonstration plots at Maslakh Range Project near Quetta. During early 1980's, this shrub received further attention by the Balochistan Soil Conservation Department when it was propagated through nursery and was planted in few demonstration plots at Mastung. Research on fourwing saltbush was started in 1985 with the establishment of Range and Livestock sections at AZRI under USAID/MART project. Since 1985, the Range Section at the Arid Zone Research Institute (AZRI) in Quetta has focused on range vegetation surveys, and on assessing the potential of exotic grasses and fourwing saltbush (*Atriplex canescens*).

Based on the results of various studies conducted by the Range Section, it is emerging that fourwing saltbush, a perennial halophytic chenopod native to the arid south-western states of the USA, is well suited for growing on land marginal for cultivation, where there is some soil but poor plant cover. Much of the range section's work is concentrated on various agronomic and utilization trials of fourwing saltbush because it appears to be the most promising technology emerging from the research efforts of the Section.

Research work on various agronomic and utilization aspects of fourwing saltbush conducted by AZRI in highland Balochistan is reviewed in this status paper:

2. Propagation and Establishment

2.1. Growth of Fourwing Saltbush Under Rainfed Conditions in Highland Balochistan:

Growth and establishment of fourwing saltbush was studied under arid climate of highland Balochistan at Arid Zone Research Institute, Quetta during 1984. Seeds of fourwing saltbush were obtained from the office of Soil Conservation Officer, Mastung. Seedlings were raised in polyethylene tubes in the first week of September, 1984. Seedlings were planted at 20-25 cm height during February, 1986. Seedlings were transplanted in circular pits of 0.65 m depth and 0.65 m diameter dug along contour ridges at 1.5 x 1.5 m spacing. The trial included one hundred twenty five seedlings planted with one irrigation of about 15 litres of water. Crescent shape contour ridges were provided as micro-catchments along the contours to collect and conserve the maximum possible quantity of surface run-off to ensure plant survival.

Three years after planting, plants were categorized on the basis of height, diameter and canopy area as big, medium and small in April, 1988. Average dry mass was also estimated by clipping nine plants from each category and drying them in oven at 90°C for 12 hours. Total dry mass production per hectare was estimated on the basis of number of plants per unit area (Afzal et al., 1992). Data were recorded after three years of production. The survival rate was 45%, while average dry mass production estimated in that

study was reported to be 1600 kg per hectare. The annual precipitation during the study period was less than 200 mm which is considered as low compared to the average figure of 250 mm. Plants in big category attained average height of 1.02 m and produced 711.63 g dry mass. Whereas, plants in medium and small categories produced 298.73 and 81.13 g dry matter per plant, respectively (Table 1). Average canopy area measured for plants in big, medium and small category plants was 2.17 m^2, 1.13 m^2 and 0.83 m^2, respectively (Afzal et al., 1992). It was reported that the difference in plant height, crown diameter and dry matter yields of plants were due to site variation (water holding capacity, infiltration rate etc.) In addition to the above factors, genetic variability was also considered as a contributing factor for difference in height, canopy cover and dry mass production.

Table: 2.1.1. Fourwing saltbush Dry Mass Production and Moisture Content at Arid Zone Research Institute, Quetta.

Plant category	Height (m)	Canopy area (m2)	Fresh mass (g)	Dry mass (g)	Moisture content (g)	Dry mass (%)
Big	1.00	1.8	1252.1	696.7	555.4	55.6
Big	0.95	2.0	1287.4	703.5	583.9	54.6
Big	1.10	2.7	1311.2	734.7	576.5	56.0
Medium	0.65	1.2	542.0	305.5	236.5	56.4
Medium	0.60	1.1	509.1	292.3	216.8	57.4
Medium	0.70	1.1	521.6	298.4	223.2	57.2
Small	0.50	0.8	141.3	82.2	59.1	58.2
Small	0.50	0.9	150.6	85.6	65.0	56.8
Small	0.45	0.8	140.0	75.6	64.4	54.0

Average dry matter per plant= 363.8 g
Average dry matter/ha at 1.5x1.5 m spacing= 1600 kg/ha
(Reproduced from Afzal et al., 1992).

It was concluded that fourwing saltbush can be raised on marginal lands of upland Balochistan through planting seedlings by establishing micro-catchments during winter rainy period with one watering at the planting time.

2.2. Competition effects on the establishment of fourwing saltbush:

A study was conducted by Aro et al., (1988) at Tomagh (Loralai) to look at the competition effects on survival and establishment of fourwing saltbush. In July 1987, 240 three months old fourwing saltbush seedlings were transplanted into 0.5 sq m to 1.0 sq m openings in the *Cymbopogon-Chrysopogon* grassland. Each transplant got four litres of water at planting time and another four litres two months later. During that period, the study site received only 27 mm of rainfall and during the next 10 months received only an additional 147 mm. Livestock grazing was excluded

from the site but rabbits were reported to have caused some damage to the young plants.

Fifty percent of the fourwing saltbush seedlings planted into the established grassland community survived the first year. At least 25% showed vigorous growth, and the twenty largest plants averaged 27 cm in height and 19 cm in diameter. These results indicated that fourwing saltbush planted into open stands of grazing stressed perennial grasses can compete with the existing vegetation if adequate soil moisture is received during first few months of planting (Aro et al., 1988).

Effects of competition on survival and growth of fourwing saltbush were also observed when saltbush seedlings were transplanted into existing *Artemisia* stands in karkhasa valley during 1990. A large number of saltbush seedlings were transplanted in February, 1991 in trenches previously dug on a hill side at Karkhasa National Park near Quetta with a good cover of *Artemisia* and other annual and perennial grasses. Inspite of the good rains received during spring season, the survival and growth of the transplants were very discouraging even one year after planting. The average survival was about 20-25% while the growth was also affected tremendously. This indicates that transplanting fourwing saltbush do not give encouraging results when planted among already existing native flora in highland Balochistan. In a study conducted in Western Texas on the establishment of fourwing saltbush within perennial grass stands, it was found that survival and growth of fourwing saltbush seedlings were significantly greater in competition free plots than in inter-spaces between rows of various species and survival decreased as height of grasses increased (Petersen et al., 1986).

In another forage reserve establishment trial at Miamgundi near Quetta, similar observations were noted regarding the competition effects of native shrubs on the growth of fourwing saltbush. About 1600 seedlings were planted on the foothills at Miamgundi during March-April, 1992. The area was prepared with the help of disc plough and the existing vegetation was removed. The seedlings were transplanted along ridges of contours prepared to conserve rain water. Just across these contours, about 2000 seedlings were also planted along gentle slopes in hand dug small pits among *Artemisia* stands without preparing land and removing existing competition. One year after plantation, distinct differences in growth response of fourwing saltbush were reported (AZRI/ICARDA, 1992). Seedlings planted along well prepared contours grew to an average height of 1 m with a similar spread of crown diameter. While those planted without land preparation under competition with *Artemisia* survived but did not grow at all. This indicates that fourwing saltbush plants can survive under competition but do not grow well as a result of root competition and less moisture availability. On the basis of these results, it was recommended that seedlings should be planted in areas where

there is enough soil for root establishment and where competition has been removed by some sort of land preparation (AZRI/ICARDA, 1992).

2.3. Vegetative Propagation of fourwing saltbush:

Direct seeding of fourwing saltbush has not produced desirable results in highland Balochistan. Germination of fourwing saltbush seeds is very low due to many factors such as hollow seeds, hard seed coat and presence of germination inhibitors like saponin (Nord and van Atta, 1960). The most common method of establishing fourwing saltbush stands in highland Balochistan is transplanting nursery grown seedlings. A study was conducted by Jasra et al., (1993), to investigate vegetative propagation of fourwing saltbush in highland Balochistan. Establishment of fourwing saltbush was studied using cuttings from mature fourwing saltbush plants at AZRI. The branch cuttings were planted in pits at 1.5 x 1.5 m spacing. After planting the pit was filled with soil to within 15 cm of the surface to allow 50 ml water harvesting. The three treatments applied were:

a) **Length of branch cutting**; s) short (15 cm), m) medium (22.5 cm) and l) long (30 cm). All cuttings were about 0.5 cm in diameter.
b) **Mode of placement in the soil**; v) vertical-two thirds of the cuttings were in the soil leaving one third above the ground and s) slanting-the cutting was planted in the soil at a 45° slope with two thirds in the soil and the rest above the ground.
c) **Season of planting**; F-second week of February, M-first week of March and A-first week of April.

Out of a total of 72 branch cuttings, only nine cuttings sprouted during spring, 1991. Inspite of good and well distributed rains during spring 1991 (235 mm), the sprouting rate was very discouraging and by the end of June, 1991 only one cutting was surviving. These results indicate that the scope for establishing fourwing saltbush through vegetative propagation under arid conditions of Balochistan may be limited (AZRI/ICARDA, 1991). However, follow up studies using growth hormones like indol acetic acid, to encourage root initiation were suggested which might increase the success rate of vegetative propagation.

Table: 2.3.1. Response of Vegetative Propagation of Fourwing saltbush in Balochistan.

Type of cutting	Cuttings planted	Cuttings sprouted	Cutting survived
small vertical February	4	1	0
small vertical March	4	1	1
small vertical April	4	0	0
small slanting February	4	0	0
small slanting March	4	1	0

small slanting April	4	0	0
medium vertical February	4	1	0
medium vertical March	4	0	0
medium vertical April	4	0	0
medium slanting February	4	0	0
medium slanting March	4	1	0
medium slanting April	4	0	0
long vertical February	4	2	0
long vertical March	4	1	0
long vertical April	4	1	0
long slanting February	4	0	0
long slanting March	4	0	0
long slanting April	4	0	0
Total	72	9	1

(Reproduced from Jasra et al., 1992).

2.4. Benefits of fertilizers, manure and micro-basin water-harvesting on fourwing saltbush establishment:

Plant density, the possible benefits of fertilizer application and manure, and two different methods of micro-basin water-harvesting, were investigated in this trial. It was initiated with the planting of nine month-old seedlings at Quetta (AZRI) and Tomagh in June 1990. At AZRI, the saltbush seedlings were planted on a site where few other perennial plants grow, whereas at Tomagh, the seedlings were planted among the native bunch grasses, *Cymbopogon schoenanthus* and *Chrysopogon aucheri*. The three treatments were:

- fertilizer: manure, N plus P, and no fertilizer (three levels)
- plant spacings: 2.5 and 2.0 m (two levels)
- water-catchment system: saucer-shaped, V-shaped (two levels)

These treatments combine to give 12 treatment combinations in a factorial design with two replicates. The fertilizer was applied to each plant as a single dose equivalent to 11.5 kg nitrogen and 11.5 kg phosphorus/ha, as Nitrophos (23.23.0, 50 kg/ha). Manure was applied to each plant at a rate equivalent to 1 t/ha. A single irrigation of 15 l/plant was applied at planting. The saucers have a diameter of nearly 2 m and the Vs have arms of 2 m length at 90° to each other. Measurements of plant survival, height and crown diameter were made every month on the same five individually tagged plants in each plot. The experiment ended in June 1993, and the biomass of leaves and wood of plants was determined using destructive methods.

Markedly contrasting growth patterns of saltbush were seen at AZRI and Tomagh, which have different levels and distributions of rainfall, as well as soils. The total rainfall during the period from July 1990 to June 1991 and from July 1991 to June 1992 was 391 and 332 mm at Quetta AZRI, respectively, and 424 and 350 mm, respectively at Tomagh. The distribution, however, at the two sites differs: at Quetta, rainfall is concentrated during winter and spring, whereas at Tomagh, rainfall during the summer monsoons makes a large contribution to the annual total. The mean minimum temperatures at Quetta and Tomagh are also different, even though the altitude at Quetta (1680 m) is slightly lower than at Tomagh (1800 m).

At Quetta, the plants are growing on soil that was transported in and placed over the underlying gravel beds that form the base of the AZRI research station. The soil is thought to be fairly fertile, although no analyses have been made. In contrast, the soils at Tomagh are very shallow, with a calcareous hardpan 15-20 cm below the surface. This would affect root development, as can be seen in the next experiment on different water-harvesting methods.

The clear effect of climate on the pattern of growth of saltbush is reflected in the increasing crown diameter of plants growing at AZRI and at Tomagh (Figure 2.1). Following planting in June 1990, seedlings at AZRI showed little growth during the autumn, when moisture but not temperature was limiting, and during winter, when temperature but not moisture was limiting growth. Growth started again in March 1991, when temperatures began to rise and was rapid until June, when lack of moisture probably started to limit growth again. A period of dormancy followed until April 1992, when growth started again. Even though growth expressed as crown diameter was less in the second summer 1992 than in 1991, it continued until October 1992, as compared with July in 1991. This may have been because more moisture was stored, following excellent rain (132 mm) in April 1992 at AZRI.

At Tomagh, a different growth pattern was seen and the plants were, in general, smaller than at AZRI. Crown diameter remained fairly constant from November 1990 until February 1991 and then increased rapidly owing to rising temperatures and good rainfall. Marked contrasts in growth, however, were seen between treatments, which are discussed below. The decrease in crown diameter in June 1991 may have been a measurement error that affected all treatments. From July 1991 until the end of the experiment in December 1992, growth continued at a steady rate, even during winter. This suggests that winter temperatures were not low enough to stop growth and sufficient moisture was generally available. Indeed, the good rainfall during the winter 1991/92 accelerated growth of the plants from October to December 1991, especially of those receiving fertilizer and manure. After a short period of relative dormancy in January and February 1992, growth continued

throughout the summer of 1992 and only slowed during the period September to December 1992, when lack of moisture may have been the limiting factor.

Only the main effects of fertilizer application on crown diameter were statistically significant at Tomagh, and these effects persisted, even when adjusted, using crown diameter in November 1990 as a co-variate. This effect can be seen in Figure 2.1. The benefits of added plant nutrients at Tomagh, but not at AZRI, suggest that the soils at Tomagh are low in fertility, compared to the soils at AZRI. This suggestion needs to be confirmed, using the chemical composition of the soils.

At AZRI, treatment effects on crown diameter were similar during the autumn and winter dormant period, but effects began to emerge during the period of rapid growth in the spring of 1991. The increased crown diameter from harvesting water in saucer-shaped basins as compared with V-shaped catchments was generally highly significant ($P<0.001$), with the statistical significance of the main effects of plant spacing and fertilizer on crown diameter being somewhat lower over the period August 1990 to December 1992. During the 10 months after June 1991, the plants growing in saucers with no fertilizer or with manure tended to have larger crown diameters than the plants in the other treatments. This difference persisted through to December 1992. When the initial differences, however, in crown diameter were removed, using the crown diameter in August 1990 as a covariate, the significance of the main effects was seldom statistically significant ($P>0.05$). There were no significant interactions between plant spacing, fertilizer application and water-harvesting design.

The conclusion drawn from this preliminary analysis of the data is that, at AZRI, growth of saltbush plants is similar under the two water-harvesting designs and that adding inorganic fertilizer or manure had little beneficial effect. In contrast, inorganic fertilizer and manure enhanced plant growth on the infertile and shallow soils at Tomagh. At both sites the height of the plants and crown diameter responded similarly to the various treatments (AZRI/ICARDA, 1992).

2.5. Comparisons of different methods of water-harvesting in fourwing saltbush establishment trial

Ways have to be found to ensure that saltbush establishes quickly after planting, without the need for additional watering. This reduces the amount of work to be performed by farmers and should make them more willing to adopt the technology. Planting has to be completed before the long, dry period in summer, and even during the planting season from December to late February rainfall can be insufficient for plant growth and survival. It is therefore important to harvest as much water as possible close to the plant.

The four ways of harvesting water investigated in the trial are:

- saucer catchments; each saucer has a 2 m diameter,
- V-shaped catchments: the Vs have 2 m arms at 90° to each other,
- contour furrows: at 2 m spacing, and
- ripping: at 2 m spacing.

Six month-old seedlings were planted in June 1990 at Zarchi and Tomagh into native range dominated by *Cymbopogon schoenanthus* and *Chrysopogon aucheri*. A single irrigation of 15 l/plant was given. The trial was laid-out as a randomized complete block design with four replicates. Survival rate, crown diameter and plant height were measured every month on the same tagged plants. Only the results from Tomagh are reported here since growth of saltbushes at Zarchi in all trials has been poor, except under irrigation. This suggests that Zarchi, with a mean annual rainfall of about 200 mm, is too dry compared with Quetta which receives annually about 250 mm rainfall. Also the soils where the trials are laid out are quite shallow and stony and thus have little water-storage capacity. These arguments are supported by the good growth of bushes at a site below Zarchi station, where the soils are better, some water can run-on to the site (known as the *sailaba* system) and there is no competition from sagebrush (*Artemisia maritima*).

During the first four months after transplanting there was some growth of the saltbushes, expressed as crown diameter (Figure 2.2). During this period soil moisture was available and minimum temperatures were above 10°C. Thereafter the crown diameter of plants decreased until January, probably due to leaf-drop and damage by rabbits which are common in the area. Beginning in January 1991, no increase in crown diameter was then seen until March. This is difficult to explain since even though low temperatures may have limited growth until April, this would not have been the case thereafter when moisture was adequate. By July 1991 a period of steady growth occurred that continued for 18 months until December 1992. This is the same finding as in the other experiment at Tomagh reported above. It suggests that once the bushes are established, they can continue to grow through winter at a rate similar to the summer period.

There were no statistically significant ($P>0.05$) effects of the different water-harvesting designs on crown diameter, although the bushes planted in furrows tended to be larger. This may be related to the better catchment of water in the furrows rather than breakage of the hardpan, since it is likely that the ripper would have broken the hardpan too but the bushes were smaller.

It is difficult to conclude from this study at Tomagh that one water-harvesting or land preparation treatment is better than the other since it is not known what role the hardpan plays in determining plant and root growth. Furthermore, the magnitude of the effect of competition from the bunch grasses is also unknown. However, from a practical standpoint ploughing would be the land preparation method of choice since it can be mechanized and appears to result in the largest plants among the treatments compared (AZRI/ICARDA, 1992). Indeed, saucers and V-shaped catchment designs would appear to be impractical due to their high labour costs. These costs have to be very low to give range improvement technologies a chance of being accepted by government agencies, let alone farmers.

2.6. Effects of watering frequency on establishment rate:

When soil moisture levels are low, it is essential to use a small irrigation to ensure the successful establishment of saltbush. This is the case when planting is after early May when little further rain is expected and is particularly true if the rainfall in spring has been poor. In several of the present experiments about 15 litres of water (a bucket-full) were applied at planting.

An experiment was conducted at Zarchi which aimed to investigate the effect of watering frequency on the performance of saltbush. The seedlings were planted in pits at Zarchi in May 1990 at a spacing of 1.5 x 1.5 m in a randomized complete block design layout with four replicates and three treatments. At each watering one bucket full of water (about 15 litres) was given to each plant. The same four plants in each treatment and replicate were sampled for crown diameter and plant height once every month until December 1992. The treatments were: 1) watering once every week, 2) watering once every two weeks, and 3) watering once a month.

The plants watered once every two weeks tended to be taller than the plants in the other two treatments and this improvement was generally statistically significant ($P<0.05$). However, the growth of the plants was poor, as in most experiments at Zarchi, despite the additional watering (AZRI/ICARDA, 1992). This finding suggests that other factors are limiting growth, such as a lack of top soil where the experiment is being conducted. Interpretation of the results is not attempted and the experiment has been abadoned

2.7. Effects of plant spacing on growth of fourwing saltbush:

Experience with forage reserves of saltbush at AZRI has shown that, if stands become too dense, they are poorly utilized by sheep and goats. The purpose of this study was to find the optimum plant density that maximizes carrying capacity. It is anticipated that the closer plant spacing will make better use of the scarce rainfall, because more will be used by the plants rather than being lost as evaporation. The life-span, however, of closely spaced plants may be shorter because of competition effects. This will be less serious, provided the plants remain small as a result of grazing.

The study is being conducted at two locations; AZRI station, Quetta, and Karkhasa National Park near Quetta (Forestry Department, Government of Balochistan). At each location, two blocks (replicates) each of 3000 m^2 and differing in their soil types, were planted with six-month old seedlings in February and March 1991. The three plant spacing treatments being applied within each block are: 1 x 1 m (10,000 plants/ha), 2 x 2 m (2,500 plants/ha) and 3 x 3 m spacing (1,111 plants/ha). Every two months, data are collected on survival rate (mortality), plant height and crown diameter. Plant biomass was estimated from the regression between plant biomass, which ranged from 0.0018 to 2.9942 kg, and plant height and crown diameter, which ranged from 15 to 110 cm and 10.5 to 135 cm, respectively, ($P<0.001$, $n = 27$, $r^2=0.90$).

Apart from ground cover, there were no statistically significant effects of plant spacing on the various parameters measured and estimated plant biomass. The expected trends, however, are sufficiently interesting to deserve comment (Table 2.7.1). Individual plant volume doubled, but plant volume per hectare decreased by about 75 percent, as plant density decreased from 10,000 to 1,111 plants per hectare. This resulted in a four-fold difference in individual plant biomass, much better ground cover and a higher rainfall-use-efficiency in closely spaced plants. Survival rate was similar across the spacing treatments (AZRI/ICARDA, 1992).

Table 2.7.1. Plant dimensions, volume, biomass, ground cover, rainfall-use-efficiency and survival at the November 1992 sampling, at three plant spacings (S) and two locations (L), AZRI & Karkhasa.

	Plant spacing (m)			SED	Sign.[1]	
	1x1	2x2	3x3		S	L
Plant height (cm)	58	62	67	10.3	ns	ns
Crown diameter (cm)	58	63	78	16.9	ns	ns
Plant volume (m^3)	0.11	0.16	0.24	0.104	ns	ns
Plant volume (m^3/ha)	1065	409	268	268.3	ns	ns
Biomass (kg DM/ha/2 yrs)[2]	2922	1123	735	-	-	-
Ground cover (m^2/plant)	0.27	0.35	0.51	0.189	ns	ns
Ground cover (percent)	26.7	8.7	5.7	10.7	*	ns
Rainfall-use-efficiency[3]	4.18	1.61	1.05	-	-	-
Survival (percent)	95.1	95.0	90.6	2.79	ns	ns

[1]Levels of significance: ns = P>0.05, * = P<0.05.
[2]Estimated from regression between biomass and plant volume.
[3]kg dry matter (DM)/mm rainfall/ha. Based on rainfall (698.6 mm) between October 1990 and October 1992.

In regions where rainfall is so low that efficient use of moisture is a priority, these preliminary results indicate that rainfall-use-efficiency can be markedly improved by using close plant spacing. During the coming season, however, the effects of inter-plant competition should become apparent, especially in the closely spaced plants which could make high plant density less attractive. Indeed, it is generally considered that a plant population of 1000 per hectare is closer to the level that allows persistency of the population. It is also unlikely that farmers will consider planting well over 1000 plants per hectare because of the high costs involved. Plants in three different treatments were grazed by sheep during summer of 1993 and further grazed after the regrowth during fall of 1993 by leaving half of the plot planted with 1x1 m plant spacing as ungrazed. Further development of both ungrazed and grazed plants will be studied during spring and summer of 1994.

3. Grazing Management

3.1. Grazing potential of fourwing saltbush pastures under deferred and continuous regimes:

It was found essential that grazing studies be conducted to investigate the carrying capacity of saltbush and its persistency.

Fourwing saltbush can withstand moderate to heavy grazing pressure (Rumbaugh *et al.*, 1982), but, without, suitable grazing management sustained production is not maintained (Jefferies and Pitman, 1986). Utilization of saltbush by animals is generally recommended after 18 to 24 months of growth (Ueckert, 1985). The adoption potential, however, of saltbush is likely to be reduced if farmers have to wait this long. Therefore, some of the saltbushes planted on farm land in March/April 1992 was grazed in December 1992.
A new grazing study on saltbush at AZRI, which also serves as a training exercise, is investigating the persistency, offtake and carrying capacity of saltbush under different grazing regimes. Since the study started late in the growing season, only a simple comparison was made of the potential of saltbush grazed in a continuous (set-stocked) or a deferred regime. The latter involved twice the grazing pressure of the continuous regime but for half the duration. Moreover, grazing in one of the deferred plots ended eight weeks before grazing in the other deferred plot and in the continuously grazed plot. This could affect the level of root reserves in plants entering the winter period and ultimately the persistency of the plants. The trial used Balochi and Harnai yearling rams. They were offered a basic diet of wheat straw, since it was anticipated that the saltbush alone could not maintain the liveweight of animals during the autumn period, when plant growth diminishes owing to a lack of soil moisture.

Two adjacent blocks (replicates) of saltbush, one of 35 x 152 m and the other of 41 x 143 m, established in the early summer of 1987 at AZRI were used. Each block was divided into three plots, and starting in July, one plot in each block was grazed continuously by five sheep for 16 weeks at a stocking rate of 28.3 sheep/ha. Grazing by 10 sheep in one of the other two plots in each block started on the same day and continued for eight weeks. The sheep were then moved to the other plot for another eight weeks. Thus the mean stocking rate in these two plots was also 28.3 sheep/ha, but one was grazed later into the autumn than the other.

At the start of the study all leaves from seven plants in each plot were removed, weighed, and dried to determine biomass available at the start of the study. Eight plants in the continuously grazed plots were protected by 1.5 x 1.5 m cages and the biomass of leaves on them measured at the end of the study. The leaf biomass of other plants exposed to grazing in each plot was determined at the end of grazing. This made it possible to

estimate the amount of leaf available at the start and end of grazing, and the amount apparently removed by the sheep. Sheep grazed from 8.00 to 12.00 h and then returned to pens for water and chopped wheat straw, which was offered at a daily rate of 500 g/sheep. Samples of straw were taken for dry matter analysis. Sheep were weighed at the start of the trial, then once a week until the trial ended.

The preliminary results from the trial are shown in Table 3.1.1. There are unlikely to be statistically significant differences between the two grazing regimes, with sheep in both treatments gaining 13 to 18 g daily. About 1100 kg dry matter (DM)/ha leaves were on offer at the start of the trial, and intakes of leaves and wheat straw were the same in the two treatments. The total intakes were about 20 g DM/kg liveweight or 47 g DM/kg metabolic body weight.

These results indicate that, in the autumn, sheep grazing saltbush need to be supplemented with wheat straw to allow modest liveweight gains (AZRI/ICARDA, 1992). The saltbush could have provided a higher proportion of the diet at a lower stocking rate but the duration of grazing would have been shorter. Currently it is not known how farmers will manage their saltbush reserves and, therefore, it is important to expand the area and number of reserves on farms, so that these can be grazed by farmers' animals. Meanwhile, grazing studies are needed which will give researchers the information necessary to advise farmers on grazing regimes that allow good offtake from saltbush reserves, without jeopardizing the persistency of the plants.

Table 3.1.1. Grazing days, liveweights and average daily gains of sheep, grazing offtake of saltbush leaves, and intake of saltbush leaves and wheat straw in a continuous and deferred grazing regime

	Continuous	Deferred[1]
Initial liveweight (kg)	29.8	27.8
Final liveweight (kg)	31.8	29.3
Average daily gain (g)	18	13
Offtake of saltbush (kg/head)		
Initial Biomass	20.0	20.0
Final Biomass	2.8	3.0

Offtake	17.2	17.0
Intakes (g DM/hd/day)		
- saltbush leaves	154	152
- straw	466	429
- total	620	581

[1]Sum of two eight week grazing periods.

The plants were cut at 8-10 inches above the ground level after the trial ended and the regrowth of these plants measured during the next spring season. The height and crown diameter of 15 randomly selected plants were measured in each plot. No statistically significant difference was found in the height and crown diameter of plants in deferred and continuous treatment plots after the pruning. This means that the plants responded in the same fashion in terms of regrowth following grazing with deferred and continuous regimes under similar grazing pressure.

3.2. Grazing management of fourwing saltbush pasture under different supplemental feeding regimes:

Another trial on grazing management of fourwing saltbush was conducted during summer, 1993. Three rams of Harnai breed were used in the three different treatments which include, fourwing saltbush grazing with no supplementation (control), fourwing saltbush grazing plus 200 g of wheat straw/head/day and fourwing saltbush grazing plus 500 g wheat straw/head/day. There were two replications for each treatment. Two adjacent blocks (replicates) of saltbush, one of 35 x 152 m and the other of 41 x 143 m, established in the early summer of 1987 at AZRI and pruned in January, 1993 were used. At the start of the study all leaves from seven plants in each plot were removed, weighed, and dried to determine biomass of fourwing saltbush available at the start of the study. Five plants in each plot were protected by 1.5 x 1.5 m cages and the biomass of leaves on them measured at the end of the study. The amount of forage contributed by annual grasses in each plot was also measured.

Each block was divided into three plots, and starting in mid June, 1993, three lambs of each replicate were grazed in each of the three sub-plots of two blocks at the stocking rate of 28.3 sheep/ha. The lambs were grazed from 8.00 to 12.00 noon and then

1700-1900 h. daily for 15 weeks. Daily wheat straw intake (g) was recorded for each group. In addition, each group was offered a known amount of water per day and the daily water intake in litres was also recorded for each group. The wheat straw was offered to each group after the first grazing session i.e., at noon while, water in known quantities was offered throughout the day and night and measured each morning after taking sheep for grazing. Sheep were weighed at the start of the trial, then once a week in the morning until the trial ended. Fourwing saltbush forage consumed by each group of lambs was measured at the end of the grazing trial by the estimation of forage on caged (ungrazed) and grazed plants.

Table 3.2.1. Grazing days, liveweights and average daily gains of sheep, grazing offtake of saltbush leaves, and intake of saltbush leaves, wheat straw and water in three different feeding regimes

	4WSB grazing alone	4WSB grazing + 200 g WS/d	4WSB grazing + 500 g WS/d
Grazing days	105	105	105
Initial liveweight (kg)	22.7	23.13	23.2
At week 9			
Final liveweight (kg)	25.7	25.4	25.4
Average daily gain (g)	48	36	35
At week 16			
Final liveweight (kg)	24.2	25.0	25.5
Average daily gain (g)	14	18	22
Offtake of saltbush (kg/head)			
Initial Biomass	54.0	45.0	42.0
Final Biomass	5.1	4.0	4.6
Offtake	49.0	41.0	37.4
Intakes (g DM/hd/d)			
- saltbush leaves	466	390	356
- straw	-	176	371
- total	466	566	727
Water Intake (l/hd/day)	3.7	3.5	3.7

The preliminary results from the trial are shown in Table 3.2.1. Sheep gained an average of 48, 36 and 35 g daily in the three treatments i.e., grazing fourwing saltbush alone, fourwing saltbush grazing + 200 g wheat straw and fourwing saltbush grazing + 500 g wheat straw per day. However, after the first nine weeks, fourwing saltbush forage became less and less available and become a limiting factor in the weight gain of sheep especially for the group solely fed on fourwing saltbush diet. At the end of fifteen weeks grazing period, the average daily gain was in the reverse order. Sheep in the group offered 500 g wheat straw each day showed maximum daily gain i.e., 22 g as compared to the other two groups. That means as the fourwing saltbush forage became a limiting factor, sheep in all the three gorups reduced their daily gain with the group lost the maximum weight fed on fourwing saltbush forage alone. These findings are helpful in determining the optimum grazing capacity of sheep fed on fourwing saltbush pastures. Also, these results would be helpful in indicating the time at which sheep need to be supplemented with wheat straw in addtion to grazing fourwing saltbush forage. This study is planned to be repeated during the next summer and fall to make concrete recommendations. There was no difference in the daily intake of water for the three treatments although daily water intake fluctuated with the rise and fall in the daily temperature (Figure .).

About 805 kg dry matter (DM)/ha leaves of fourwing saltbush were on offer at the start of the trial, and the intake of leaves of fourwing saltbush was higher for the group fed on fourwing saltbush forage alone, however, there were no statistical differences in the fourwing saltbush intakes for the three treatments. The total intakes were about 20 g DM/kg liveweight or 47 g DM/kg metabolic body weight. About 228 kg DM /ha of annaual grasses and forbs were also available for sheep during the grazing period in all the three treatments.

These results indicate that, in the autumn, sheep grazing saltbush need to be supplemented with wheat straw to allow modest liveweight gains. The saltbush could have provided a higher proportion of the diet at a lower stocking rate but the duration of grazing would have been shorter. Currently it is not known how farmers will manage their saltbush reserves and, therefore, it is important to expand the area and number of reserves on farms, so that these can be grazed by farmers' animals. Meanwhile, grazing

studies are needed which will give researchers the information necessary to advise farmers on grazing regimes that allow good offtake from saltbush reserves, without ieopardizing the persistency of the plants.

The plants were cut at 8-10 inches above the ground level after the trial ended, the regrowth of these plants will be measured during the spring of 1994. The height and crown diameter of 15 randomly selected plants will be measured in each plot.

4. Nutritive value of fourwing saltbush

4.1. Fourwing saltbush Forage Compared with Conventional feeds For Yearling Sheep:

The study was conducted at the Animal Nutrition Unit, AZRI to determine the acceptability and nutritive value of fourwing saltbush when compared with other more conventional feeds for sheep. Twenty-four yearling Harnai sheep of approximately the same weight and age were randomly divided into the groups of eight animals each, with four males and four females in each group. Each of these groups were randomly assigned to be fed one of the following rations:

Ration A:	Fourwing saltbush (600 g/day/animal)
ration B:	Lucern hay (600 g/day/animal)
Ration C:	Wheat Straw (500 g/day/animal)+ barley grain (100 g/day/animal)

Fourwing Saltbush was collected daily from a saltbush stand growing at AZRI. Each animal was fed individually and the weights of daily feed consumed and refused were recorded. The feeds were available to the animals from 8.00 am to 4.00 pm. The total feed intake was calculated on the dry matter basis. Animals were offered drinking water for 30 minutes after eve y two hours during the feeding period, and after that they had f ee access to the drinking water. The duration of the study was f ur weeks, during February and March, 1988. The following data wer recorded during the study:

a) initial body weight of each animal
b) weekly body weight gain/loss of each animal
c) daily feed offered/refused by each animal
d) palatability index was calculated by the following formula:

$$\text{Palatability Index} = \frac{\text{FEED INTAKE}}{\text{FEED OFFERED}} \times 100$$

There was a continuous rise in the uptake of all rations after the second day of feeding. By the ninth day, the palatability index became almost stable at 99%, 98% and 69% for lucern hay, fourwing saltbush and wheat straw + barley, respectively. Data in Table 4.1.1 show that the sheep were consuming about 90% of fourwing saltbush and lucern by the sixth day, but less than 60% the wheat straw and barley ration. No difference in the uptake was observed between sexes. There was a drop in liveweight under all feeding treatments at the end of first week (Table 4.1.2). At the end of two weeks, the lucern hay and wheat straw-barley grain groups had apparently started to regain some of their weight lost during the initial feed adjustment. The fourwing saltbush group showed a steady weight level from the initial drop to the end of the third week, then in the last week of the study, started to gain some weight. The difference in the weights for the three groups was significant at the end of three weeks and four weeks. Differences in the performance of male and female groups were not statistically significant (Atiq-ur-Rehman et al., 1988).

Table: 4.1.1. Palatability Indices of Three Rations Fed to Yearling Sheep.

	Days from start of experiment									
	1	2	3	4	5	6	7	8	9	10
Fourwing Saltbush	41	36	42	53	82	92	98	98	98	98
Wheat Straw	36	34	38	50	52	56	66	68	69	70
Lucern Hay	46	43	49	62	72	90	99	99	99	99

Table: 4.1.2. Yearling Sheep Weights (KG) Under Three Different Feed Regimes.

Feeds	Weeks						
	0	I	II	III	IV		
Fourwing saltbush	22.5	20.3	20.3		20.3	20.6	
Wheat Straw + Barley			21.6	20.3	21.0	21.1	21.3
Lucern Hay	22.6	20.7	22.0		22.1	22.6	
Mean	22.2	20.4	21.1		21.1	21.5	
Standard Error	0.40	0.41	0.45		0.37	0.36	
	NS	NS	NS	*	**		

Probability Levels:

* 0.05

** 0.01

NS Non Significant

(Reproduced from Atiq-ur-Rehman et al., 1988).

The drop in the live weight of all groups at the beginning of the experiment was reported to be the result of non-adjustment of rumen microflora to the new foods (Preston, 1985). The uptake of every feed was low in the first six days and this likely accounts for loss in the body weight recorded during the first week. The results of this study show that fourwing saltbush could meet the maintenance requirements of sheep and goats. The results of this study also show that fourwing saltbush forage was more palatable than the wheat straw + barley grain ration (Atiq-ur-Rehman et al., 1988). Fick et al., (1973) and Benahmed and Dulphy (1985), also reported that supplementing straw with barley grains only increased straw intake and improves the energy balance of sheep, but in contrast, nitrogen intake was very small. Reports have shown that by providing additional source of energy like stubble, straw and other energy roughage, *Atriplex* forage can supply a well balanced ration which could lead to a significant live weight gain under this productive grazing system (Le Houerou, 1992).

4.2. Nutritive Evaluation of Fourwing Saltbush in Growth and Digestibility Trials with Harnai Lambs:

Nutritive value of fourwing saltbush was investigated for growing lambs in a study during 1989 at AZRI, Quetta. Twenty four Harnai lambs were divided into three groups of eight animals each and each group fed daily 4 kg of one of the following three rations : wheat straw and lucern hay (24:76), fourwing saltbush and cottonseed cake (71:29), and wheat straw and cottonseed cake (59:41). All the animals were let out for grazing in the dormant native range for about three hours in the afternoon. The rations were offered to the animals in groups @ 500 g/head/day. The animals were given fourteen days to adapt to the new feeding regimes, after which the actual growth trial started which lasted for eight weeks. The following observations were recorded:

1. Initial body weight of each lamb after the adaptation period.
2. Daily feed offered/refused.
3. Weekly body weight gain/loss.
4. Mortality, if any.

After the end of growth trial, a digestibility trial was also conducted. Four animals from each group were randomly selected. A complete record of their daily feed intake and faeces voided was maintained individually for seven days. Daily feed offered and refusal samples were saved and stored at room temperature for later analysis. The results indicated the body weights of the animals did not differ during the first four weeks of the study. During the 5th, 6th, 7th, and 8th week of the growth trial, the body weights of lambs fed ration 1 (lucern hay and wheat straw) and ration 2 (fourwing saltbush and cottonseed cake) were not different, but were significantly lower ($P<0.01$) than those of lambs fed on ration 3 (cottonseed cake and wheat straw). The crude protein content of the three rations fed were same. However, ration 3 contained higher TDN (60%) as compared to ration 1 and 2 which contained 53% and 50% TDN respectively. This indicates that although ration 1 and 2 contained enough nutrients for maintaining the body weight of the animals, ration 3 provided more nutrients as compared to the other two rations which reflected on the better performance of the animals. The dry matter intake and crude protein digestibility did not differ between the three rations (Table 4.3). However, the dry matter, acid detergent fiber and neutral detergent fiber digestibilities of the ration containing fourwing saltbush were

lower than the other two rations possibly because of lignification process. Lambs given ration 3 (CSC + WS) performed better than those on the other two treatments indicating that the supply of supplementary nitrogen and energy from cottonseed cake might have improved the fibre utilization of wheat straw. It can be concluded from the study that lambs can atleast be maintained on a ration containing 71% saltbush.

Table: 4.2.1. Intake and Digestibility of Lambs Fed Different Rations.

	Rations			
	1	2	3	
	WS+LH[1]	FWSB+CSC	WS+CSC	SED[2]
Dry Matter Intake (g)	449	472	458	
Digestibility (%):				
-dry matter	57.9[a3]	41.3[b]	57.0[a]	3.1
-crude protein	70.3	70.8	71.1	1.7
-acid detergent fiber	50.6[a]	13.2[b]	45.2[a]	3.9
-neutral detergent fibre	49.3[a]	21.6[b]	49.2[a]	4.0

[1] WS+LH = wheat straw+ lucern hay; FWSB+CSC = fourwing saltbush + cottonseed cake; WS+CSC = wheat straw + cottonseed cake.
[2] standard error of difference.
[3] values in the same row with different superscripts differ significantly ($P<0.05$).
(Reproduced from Atiq-ur-Rehman et al., 1990).

4.3. Fourwing saltbush as a Winter Maintenance Forage for sheep Grazing Highland Balochistan Rangelands:

Nutritive value of fourwing saltbush was investigated as a winter maintenance browse in comparison to native range grazing with or without protein or energy supplementation. The study was conducted at Tomagh Range-livestock Research Station in Loralai District in November, 1988 for 10 weeks. Sixteen Harnai lambs, six to seven months of age, were divided into four groups of four lambs each. Each of the four groups was randomly assigned to one of the

following treatments:

1. Fourwing saltbush grazing alone;
2. Range grazing + lucern hay @ 100 g/head/day
3. Range grazing + barley grain @ 100 g/head/day
4. Range grazing alone

Lambs in the first treatment grazed in four 10x17 m blocks of fourwing saltbush established in 1987 and shifted weekly from block to block while all other lambs in treatment 2, 3 and 4 grazed native mixed grass-shrubland range . The grazing time for all lambs under all treatments was eight hours i.e., 0800 hours to 1600 hours. The lambs in the treatment 2 and 3 were fed their supplementary ration individually late in the afternoon. All animals had equal access to the drinking water in the morning and evening.

The data on live weight changes, and cumulative metabolic weight changes are summarized in Table 4.4. The two range grazing plus supplementation treatments produced weight gains which were not significantly different from each other. Except for the first three weeks of the study period, both of these treatments yielded significantly higher weight gains ($P<0.05$) than did range grazing with no supplementation (Atiq-ur-Rehman et al., 1990). Fourwing saltbush grazing provided cumulative weight gains at the end of Ist, 3rd, 4th, 6th, 7th, and 8th weeks which were not significantly different from the range grazing plus the lucern hay treatment. At the end of 4th and 10th week, weight gains by lambs on fourwing saltbush treatment were similar to those on the range grazing plus the barley grain treatment. The fourwing saltbush treatment was significantly different from range grazing with no supplementation, only at the end of 4th week when animals in the later treatment experienced a sharp drop in average weight. Lambs browsing fourwing saltbush as their sole diet gained an average of 6 percent in body weight over the 10-weeks period. This compares with weight gains of 5.8, 10.3, and 12.9 percent, respectively, for range grazing without supplementation, range grazing with barley grain, and range grazing with lucern hay treatments. Towards the end of the study there was an apparent decrease in the average quality of fourwing saltbush forage consumed due to decreased intake of more leafy foliage. This study concluded that under fourwing saltbush grazing alone, lambs can not only maintain their body weights but also gain some weight (Atiq-ur-Rehman et al., 1990).

Table: 4.3.1. Weekly Liveweight Responses to Different Grazing and Feeding Treatments by lambs.

Treatment	Weeks 0	1	2	3	4	5	6	7	8	9	10
Fourwing saltbush grazing alone	12.30	12.35	12.05	12.35	12.55	12.60	12.98	12.90	13.35	13.20	13.25
Range Grazing + Lucern hay (100 g/h/d)	13.25	13.55	14.35	13.85	14.00	14.45	14.40	14.35	14.90	15.30	15.60
Range Grazing + barley grain (100g/h/d)	12.40	12.65	13.20	13.25	12.95	13.65	13.90	14.00	14.40	14.55	14.15
Range Grazing alone	12.75	12.55	12.80	12.55	12.05	12.65	12.80	12.90	13.15	13.55	13.75

Reproduced from Atiq-ur-Rehman et al., 1990

4.4. Fourwing saltbush as a supplement to basic diet of wheat straw:

Saltbush is being studied for its potential both as a supplement to grazing on rangelands which are generally heavily degraded owing to over population of small ruminants and removal of the shrubs, for fuelwood and as a supplement to other feeds such as wheat straw. A study was conducted at AZRI to investigate the value of saltbush as a supplement to a basic diet of wheat straw purchased from the local market. Effects of feeding saltbush on levels of sodium, calcium, phosphorus and potassium in the blood were studied and daily water intake was recorded.

The study had three phases. In a standardization phase of six days, sheep were offered *ad-libitum* chopped wheat straw and 200 g daily of un-decorticated cottonseed cake (CSC), containing about 20 percent crude protein in the dry matter (DM). During the main experimental phase which lasted for 28 days, four groups, each containing four mature Harnai male castrates, were offered *ad-libitum* wheat straw in addition to one of four levels of sun-dried saltbush (*A. canescens)* leaves hand-harvested in November and December 1991. The four levels were 150, 300, 450 and 600 g of leaves (air dry matter). Faeces were collected during the last 7

days of the experimental period. Feed, refusal and faecal samples were dried and ashed according to standard procedures and intakes of dry matter (DMI) and organic matter (OMI), and digestibility of the dry matter (DMD) and organic matter (OMD), and D value, were calculated. (D value is the amount of organic matter digested per 100 g dry matter ingested.)

The final phase of the experiment lasted 13 days, when sheep were again offered *ad-libitum* wheat straw and 200 g CSC. Faeces from one sheep in each group were collected, so that the digestibility of the wheat straw/CSC diet could be calculated.

There was a tendency for the DMD and OMD to remain the same at the low and medium levels of feeding saltbush leaves and then to decrease at the higher levels. The treatment differences, however, were only significant in the case of the OMD (Table 4.4.1).

Table 4.4.1. Digestibility of dry and organic matter, D value, daily intakes of dry and organic matter, and daily gains of sheep offered diets containing four different proportions of saltbush leaves and wheat straw.

	Proportion FWSB in total DMI				SD[1]	Sign.
	Low (0.15)[2]	Medium (0.29)	High (0.49)	V. high (0.69)		
Number of observations (n)	4	3[3]	4	3[3]	-	-
Digestibilities (%)						
- dry matter	52.4	53.3	48.9	44.4	4.41	ns
- organic matter	54.7	54.3	50.1	43.3	4.68	*
- D value	48.2	47.0	42.2	35.7	3.90	**
Total intakes (g/day)						
- dry matter	892	939	836	765	61.2	*
- organic matter	785	814	707	631	54.3	**
- dry matter ($/W^{0.75}$)	66.8	74.0	63.3	58.2	8.4	ns
- organic matter ($/W^{0.75}$)	58.8	64.0	53.5	48.1	7.2	ns
Daily gains (g)	41	10	-14	-100	39.8	*

[1]Residual standard deviation can be used to calculate standard errors for comparisons of treatments where the n contributing to each mean differs.

[2]Actual proportion of saltbush leaves in the diet.
[3]One sheep in each of these treatments refused large amounts of saltbush leaves and for this reason the data were not included in the analysis (AZRI/ICARDA, 1992).

There were statistically significant differences between the treatments in terms of DMI and OMI (Table 4.4.1). Definite trends were apparent. The total intakes at the low and medium levels of inclusion of saltbush leaves were similar but decreased as the proportion of saltbush leaves in the total diet increased.

Linear regression analysis was conducted between the proportion of saltbush leaves in the total diet (S) and DMD, OMD, DMI and OMI (Table 4.4.2). This made it possible to estimate the digestibilities and intakes for diets containing wheat straw only and saltbush leaves only. The DMD and OMD of the wheat straw were high, and conversely, the DMD and OMD of the saltbush leaves low. The digestibility of straw from the local landrace of wheat has not yet been determined at AZRI and there is no information about the origin of the straw. One would expect *in vivo* DMD values up to 50 percent. Indeed, the best wheat straw determined by ICARDA in Syria reached 44 percent (PFLP, 1987). The DMD and OMD values of the wheat straw used in this experiment are therefore surprisingly high. Similarly, the DMD and OMD values of the saltbush leaves are surprisingly low.

The decreasing OMI and digestibility in the total diets as the proportion of saltbush leaves increased is reflected in the decreasing liveweight gains of the sheep (Table 4.4.2). The sheep would have been neither gaining nor losing liveweight at a saltbush proportion in the total diet of 0.38.

Table 4.4.2. Constants of linear regressions between dry matter (DMD) and organic matter (OMD) digestibility of the total diet, and daily total dry matter (DMI) and organic matter (OMI) intakes, and the proportion (S) of saltbush leaves in the total diet.

Y	a[1] (SE)	b (SE)	R	P	RSD	S[2]
DDM	55.6 (2.55)	-14.4 (5.73)	0.58	0.0274	4.37	41.2
DOM	58.5 (2.77)	-19.3 (6.21)	0.67	0.0091	4.74	39.2
DMI	977.7(32.69)	-299.9(73.38)	0.76	0.0015	56.0	677.8
OMI	869.9(27.31)	-338.8(61.29)	0.85	0.0001	46.8	531.1

[1]These values indicate the estimated values for diets containing no saltbush leaves.
[2]When S=1, the diet contains 100 percent saltbush leaves (AZRI/ICARDA, 1992).

It was only possible to get the sheep to eat close to the highest level of saltbush leaves by limiting the amount of wheat straw on offer. This finding is in marked contrast to an earlier experiment in which sheep consumed, without difficulty, 700 g daily (air-dry basis) of saltbush leaves, even when offered 400 g daily of barley grain or cottonseed cake as well (Atiq-ur-Rehman, unpublished data). One possible explanation for these contrasting results is that, in the present study, the leaves were harvested late in the season, when their digestibility was low, whereas in the study of Atiq they were harvested in June.

Further studies are needed before it can be stated that saltbush harvested at the beginning of winter has a feeding value below the maintenance requirement of local sheep. It appears, however, that sheep browsing on saltbush late in the season would also need to be fed wheat straw, if the range grazing were poor as is usually the case.

5. Seedling multiplication

5.1. Seed Production:

Fourwing saltbush is an excellent seed producer, with seed matures from October to December. Seed dries on the plant and allows some flexibility in harvesting. There are about 60,000-80,000 seeds per kilogram. Seed is enclosed in bracts, forming four projected fringed wings united in a thick body over the seed. AZRI has established large reserves of fourwing saltbush at its farm which are used to collect healthy seed for raising seedlings under nursery conditions.

5.2. Seed Treatment/Removing Seed Wings:

The bracts of the seed are reported to contain a chemical compound known to inhibit germination. It is preferred to dewing the seed before sowing either through a hammer mill or just rubbing the seed between bricks or sand papers. Another general practice is

to soak the dewinged seeds in water for 24 hours before sowing which helps to dissolve any chemical compound as well as softens the hard seed coat/testa.

Removing the wings of saltbush enhances germination rate and previously was a laborious manual task involving rubbing the seed between a brick and a piece of canvas. To accelerate this process, an electrically powered dewinger was constructed by staff of the Farm Machinery Institute (FMI) at NARC, Islamabad. It is rather like a food processor/blender, except that it has four rigid and blunt steel bars at right angles to each other that form a cross. They rotate at high speed within a steel container. The machine is now being used at the AZRI nursery.

5.3. Nursery Seedling Production:

Polyethylene bags of size 8 x 4 inches (average) are filled with a mixture of soil and sand (1:1) and seeds are sown (2-3 seeds per bag) and watered daily till germination. About 30-35% seeds are reported to be empty (without embryo). The average germination percentage is around 30-40%, therefore, it is advisable to sow 2-3 seeds in the each polythene bag. Intact seeds of fourwing saltbush do not germinate under field conditions and can only be raised as seedlings in nurseries. This seems to be related to the thick protective seed coat as well as to certain chemical inhibitors. The only possible way to grow this shrub is through nursery seedling production. Germination takes place in about 7-10 days in spring, summer and early autumn. In winter, germination takes place in about 3-4 weeks time. It is preferred to leave one healthy seeling per bag. Seedlings attain a height of about 25-30 cm in 4-5 months time in spring and summer seasons.

6. Transplanting Seedlings

6.1. Time of Planting:

At nursery, seedlings should be pruned (cut in half) at 3-4 months age (8-10 inches height) to encourage lateral shoot growth. Seedlings are generally recommended to be transplanted at 4-5 months age. The recommended time of planting seedlings is in winter rainfall season i.e., from late January to the first week of April. However, planting can be carried out throughout the year if irrigation is available. Under rainfed conditions, first watering

of about one bucket (10-15 litres)/plant is recommended at the time of planting to help plant establish its roots.

6.2. Site Selection for Planting:

Selection of a proper site is essential for the successful establishment of this plant. Fourwing saltbush is best suited to the areas with 250-300+ mm annual rainfall in highlands of Balochistan including Quetta, Mastung, Muslimbagh, Pishin, Qila saifullah, Loralai etc. It can successfully be established on fallow, land marginal for cultivation as well as on gravelly fans having deep soils and less competition from local species. The shrub seedlings are very intolerant of competition from grasses and local shrubs like *Artemisia* and *Haloxylon* spp. etc.

6.3. Planting Methods:

Fourwing saltbush can be planted in pits (1.5 ft deep and 1.5 ft wide) to collect and store rain water. It can also be planted in ripped lines made by the tractor with less cost of digging pits. For fourwing saltbush forage reserves, the plant to plant distance should be 2 x 2 m. But the plant spacing could be changed according to the type of planting. For example, if planted as intercropping with the wheat, the plant to plant distance should be 1 x 1 m and row to row distance should be 4 x 4 m. Similarly if planted along bunds of cropped areas, the plant to plant distance should be 1 x 1 m which could also serve as a hedge against wind erosion.

7. Technology Transfer

7.1. Dissemination of technology through Productivity Enhancement Programme:

During 1992, an amount of Rs. 1.5 million was allocated through Productivity Enhancement programme (PEP) of Pakistan Agricultural Research Council (PARC) to expand the existing fourwing saltbush nursery at AZRI, and start planting the shrub on farmers fields as demonstration plots on marginal land. The programme was started in Range Section of AZRI on Ist January, 1993 with the following objectives:

- to increase fourwing saltbush seedling production under nursery conditions

- to plant fourwing saltbush seedlings on farmers fields as forage reserves

- to disseminate this technology among farmers through farmers field days, training workshops and collaboration with provincial livestock and Forest Departments and NGOs involved in range/forage improvement work in Balochistan.

During the first year of the project, the following jobs were carried out for disseminating the saltbush technology among farmers of highland Balochistan:

7.1.1. Nursery Seedling Production

As already mentioned, the capacity of the forage shrub nursery at AZRI to hold seedlings was about 25,000 seedlings till December 1992, but the nursery expansion work at AZRI was started in January, 1993 and by the end of April 1993, the initial target of 200,000 seedlings was achieved. Efforts are also being made to convince provincial Livestock and Forest departments as well as NGO's like BRSP and various FAO and ADB projects to establish their own nurseries in order to meet the demand of fourwing saltbush seedlings.

Seedlings of other promising *Atriplex* species like *A. lentiformis*, *A. amnicola* and *A. nummularia* and *Salsola vermiculata* are also being multiplied at AZRI nurseries to evaluate their performance under field conditions.

7.1.2. Site Selection/Transplanting Seedlings at Farmers Fields

The on-farm testing of a technology with the full involvement of farmers puts the technology to its greatest test, since, if it is not adopted by farmers, then the preceding research is of little value. This is especially the case in developing countries where the research resources of national programs are desperately short. For this reason, AZRI started establishing saltbush forage reserves under MART/AZR project in 1988 at Zarchi and Kovak. In 1990, it planted saltbush in the buffer zones of its water-harvesting trials, and, in 1991, started inter-cropping studies at two sites in Spezand. A new site, at Miangundi near Hazarganji Chiltan

national Park, was added in 1992.

Under PEP, fourwing saltbush planting campaign was started in January, 1993 at various farmers fields around Quetta and more sites were added later around Pishin, MuslimBagh, Qila Saifullah, Loralai, Barkhan, Kalat, Kovak, Kanak (Mastung) areas in collaboration with the ADB Livestock Extension Project, NGO's like BRSP, FAO Inter-regional Upland Conservation Project, Kanak Valley, Mastung, EC financed project on livestock development and FAO/UNDP Integrated Range and Livestock Projects being operational in Balochistan.

The seedlings are being transplanted in various patterns depending upon the consent and demand of the collaborating farmers. The various treatments are, 1x1 m spacing between plant to plant along bunds of cultivated area in the form of hedge, in 1x4 m spacing arrangements with plant to plant distance of 1x1 m and row to row distance of 4x4 m. This spacing was used in order to allow enough space between rows so that the farmer can plant cereal or any other fruit or vegetable crop like water melon or wheat etc. in between the rows. The forage reserves were also established as block plantation of fourwing saltbush with 2x2 m plant to plant distance. The detail of fourwing saltbush seedlings transplanted under PEP project at various locations in highland Balochistan is given in table 7.1.1.

Table. 7.1.1. Sites planted with fourwing saltbush seedlings till March, 1994:

Name of Site	Area planted (acres)	Planting Time	No. of Plants
Nohesar Rindozai (AZRI)[1]	1.50	February, 1993	1800
Kili Pir wali (AZRI)[1]	0.50	March	500
Sinjdi/Akhbarg (AZRI)[1]	8.00	March/April	8000
Pishin (LED)[2]	0.25	April	300
Sara Gur Gai (LED)[2]	2.00	March/August	1500
Panjpai (BRSP)[3]	0.25	July	400

Muslim Bagh (BRSP)[3]	small plot	July	100
Qila Saifullah (LED)[2]	small plot	July	200
Kuchlak (LED)[2]	small plot	July	100
Nichari, Pandaran(BRSP)[3] (Distt. Kalat)	0.25	August	250
Kanak valley (FAO)[4]	2.00	September	1500
Sinjdi/Akhbarq (AZRI)[1]	2.00	October	2000
Habib Zai (Pishin) (LED)[2]	0.50	November	400
AZRI, Quetta (AZRI)[1]	2.00	November	1000
Kalat (BRSP)[3]	0.50	December	400
Barkhan (BRSP)[3]	0.50	December	500
Panjpai (BRSP)[3]	0.50	January, 94	400
Kanak, Mastung (FAO)[4]	2.0	January	2000
Hyderzai, Pishin (LED)[2]	0.50	February	330
Sanjavi, Dukki, Kohlu, Barkhan and Loralai (LED)[2]	4.0	February	3900
Kuchlak, Quetta (LED)[2]	1.00	February	1400
Sariab, Quetta (LED)[2]	1.00	February	1000
Sara GurGai, Quetta (LED)[2]	1.00	February	1000
MianGundi, Quetta (AZRI)[1]	1.00	February	2000
Hazarganji, Quetta (AZRI)[1]	1.00	March	2000
Qila Saifullah (LED)[2]	2.00	March	2500
Qila Saifullah (LED)[2]	2.00	March	2000

Qila Saifullah (LED)[2]	2.30	March	2300
Muslimbagh (LED)[2]	2.50	March	2500
Muslimbagh (LED)[2]	2.00	March	2000
Saragurgai (LED)[2]	0.50	March	400
Kovak (Kalat) (AZRI)[1]	2.00	March	2000

LEGEND:

1= Arid Zone Research Institute
2= ADB Livestock Production Extension Project
3= Balochistan Rural Support Programme
4= FAO Inter-regional Upland Conservation Project:Kanak valley, Mastung
5= FAO Integrated Range & Watershed Management Project, Balochistan

7.1.3. Collaboration with the agencies/departments

In order to effectively transfer fourwing saltbush technology among farmers of highland Balochistan, necessary collaboration was started among AZRI and provincial Forest and Livestock Departments as well as various NGOs working on forage/fodder crops in Balochistan. For this purpose, a training workshop on "seedling production and planting techniques of fourwing saltbush" was organized during May, 1993 in which 17 workers/field officers participated from Agric. Extension/Forest Deptt./ADB Livestock Extension Project as well as NGOs like Balochistan Rural Support Programme (BRSP) and Mercy Corps International (MCI). The participants were given hand-on training in seedling production techniques and were taken to various sites where AZRI has established fourwing saltbush forage reserves on various farmers fields. Collaboration was also started with "Inter Regional participatory Upland Conservation and Development Project-Kanak valley, Balochistan" for planting fourwing saltbush on marginal lands with a farming system approach. The campaign of Planting fourwing saltbush as forage reserves was also strengthened with the collaboration of Livestock production Extension (ADB project) which have developed several nuclei stations for establishing demonstration plots in about 15 districts and tehsils of highland

Balochistan. The project personnel have started planting fourwing saltbush in these nuclei in collaboration with AZRI PEP project personnel. They have planned for planting about 20,000 seedlings at these stations during the winter and spring season of 1994.

7.1.4. Trainings/Visits/Farmers field days

In order to popularize fourwing saltbush technology among farmers of highland Balochistan, visits of professional extension staff of forest and Livestock departments and farmers field days were arranged during May and June, 1993. A group of fifteen Animal Production Officers (APOS)/Stock Assistants visited AZRI range shrub nursery and field area and were explained the techniques about raising and planting fourwing saltbush on farmers fields. These professionals represented fifteen Districts/Tehsils of highland Balochistan and each one of them committed to establish one demonstration plot of fourwing saltbush on farmers fields in his own target area. The planting campaign would start during the coming winter season, 1993-1994.

Two farmers field days were also organized at AZRI fields during June and July, 1993. In the first field day, livestock farmers representing Quetta, Pishin, Kuchlak, Mastung, Panjpai, Muslimbagh, Qila saifullah and Loralai areas participated through Livestock Extension Department. The other farmers day was organized in collaboration with Inter Regional Upland Conservation and Development Project in July, 1993. About 25 farmers from kanak and Noza valleys participated in the farmers filed day. The farmers were briefed/demonstrated the techniques of raising and planting fourwing saltbush seedlings at AZRI fields. They were also taken to various sites where AZRI has established forage reserves on farmers fields.

Another training course was organized under PEP project on November 9-10, 1993 in which 6 progressive farmers from Kanak valley, Mastung participated. These farmers were arranged by the Inter-regional upland conservation project-Kanak, Mastung funded by the Italian Govt. and FAO. During the two days training, the farmers practised to raise fourwing saltbush nursery and planting techniques at AZRI fields.

8. Constraints/problems with saltbush technology

Although sufficient knowledge has been gained to say that fourwing saltbush has the potential for arid climate of Balochistan in terms of its forage as well as fuelwood value, its large scale plantation on marginal lands and adoption by the farming community needs some caution and on-farm testing with full participation of farmers. Main constraints/problems are described as under:

1. For any range technology to be adapted by farmers has to be a zero cost or minimum cost technology. The biggest problem with the fourwing saltbush is that intact seeds do not germinate under field conditions and can only be raised as seedlings in nurseries. This seems to be related to the thick protective seed coat as well as to certain chemical inhibitors. This would bring some cost to this technology for seedling production. It would remain to be seen for any large scale campaign whether or not Government would provide seedling free of cost to the farmers. At present, seedlings are provided free of cost for establishing forage reserves on farmers lands as demonstration sites to popularize this technology among farmers.

2. Planting fourwing saltbush on steep gravelly slopes has resulted in poor growth and high mortality due to less moisture available through the long dry summer. Research on the establishment of fourwing saltbush on various sites has shown that this plant is best suited to the marginal lands (either cultivated or fallow) and gravelly fans (foot hills) where there is less competition from the existing plant communities as well as enough soil to support a good growth under moisture stress conditions. For that matter, some soil working like deep plough or ripping will be involved on heavily degraded gravelly fans. However, less efforts would be required to plant this shrub along ridges and bunds of already cultivated areas or intercropping with 1x4 m spacing as already described. Necessary information would still be needed to find out the best possible way to fit this plant into agro-pastoral systems of highland Balochistan.

Inspite of the above constraints/problems associated with the saltbush technology, there is a potential that this technology will be adopted by the farmers if a carefully organized campaign built on a solid information base concerning its ecology, grazing management, and farmers perceptions is carried out on a large scale

on farmers fields.

9. Future Priorities/Recommendations

On-farm testing of fourwing saltbush will be given priority by expanding the area under saltbush plantation on marginal as well as salt affected areas owned by the farmers. The specific aspects of fourwing saltbush to be studied in future include:

1. Survival, growth and productivity of fourwing saltbush under various plantation regimes like intercropping, planting around ridges and bunds and as forage reserves on gravelly fans.

2. Pruning studies on fourwing saltbush to estimate fuelwood as well as regrowth potential.

3. Grazing management studies by sheep and goats for optimum utilization and sustained forage productivity of fourwing saltbush.

4. Farmer perception and adoption studies for evaluation of fourwing saltbush technology.

5. The main activity will be the expansion of the area planted with fourwing saltbush on marginal land owned by farmers and the establishment of saltbush forage reserves in collaboration with provincial departments as well as NGO's. Both these activities will be supported by the funds which are available under the Productivity Enhancement Program (PEP) of PARC.

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