

Growth behaviour of apple cactus (*Cereus* species) in hyper-arid environment

Ahmed A. ElObeidy

Department of Fruit Horticulture, Faculty of Agriculture, Cairo University, Giza, Egypt. E-mail: elobeidy@hotmail.com.

Abstract

Introducing new crop with high water use efficiency into the hyper-arid environment will participate in curb rising demand of water. Apple cactus (*Cereus* species) characteristics fit with most of the requirements of a drought tolerant crop with very high water-use efficiency. Several *Cereus* species were introduced into a desert, characterized with rare rainfall and high temperatures. The introduced fruiting species were *Cereus hexagonus*, *C. peruvianus*, *C. peruvianus monstrose* and *C. validus*. *C. pachanoi* was introduced as a rootstock. *C. peruvianus* cuttings survived storage up to eight months. Horizontal position of the cuttings during storage encouraged the development of lateral branches. Plants were propagated by cuttings, acclimatized and then transplanted into the field in the desert. Growth and development of the introduced species were assessed under the new environment. All the introduced species grew successfully except *C. validus* that was eliminated during the first summer. *C. peruvianus monstrose* was characterized with dramatic contraction of the stem in the dry condition. The main stem of *C. peruvianus*, *C. peruvianus monstrose*, *C. hexagonus* and *C. pachanoi* grew 9.2, 10.2, 8.1 and 15 cm/month, respectively. *C. peruvianus* developed the highest number of sprouts. *C. Peruvianus*, *C. peruvianus monstrose* and *C. hexagonus* unite with the *C. pachanoi* to form successful grafts with percentage of success 80, 53 and 86.5, respectively. *C. validus* failed completely to unite with *C. pachanoi*. *C. peruvianus* and *C. peruvianus monstrose* were the most promising in the new hyper-arid environment in terms of adaptability and healthy growth.

Key words: Apple cactus, *Cereus*, drought resistance, hyper-arid environment, water use efficiency.

Introduction

As a natural hazard, drought imposes differential vulnerability on society in the hyper-arid region (Wilhite, 2000). Introducing new crops with high water use efficiency in the hyper-arid environment will participate in curb rising demand of water (ElObeidy, 2004). Apple cactus (*Cereus* sp.) characteristics fit with most of the requirements of a drought tolerant crop with very high water-use efficiency. Apple cactus has physiological and morphological methods of exploiting environments that would soon desiccate other plant species (Nerd *et al.*, 1988; Wallace and Gibson 2002). In addition, apple cactus is characterized with crassulacean acid metabolism pathway that improve water-use efficiency (Malda *et al.*, 1999; Cushman and Borland, 2002).

Apple cactus, a popular group of cacti from South America, consists of about 60 species. These vigorous-growing cacti are easy to grow in marginal, infertile, dry lands where common crops fail (Felger and Moser, 1976; Wallace and Gibson 2002). Apple cactus produces unique fruits that are thornless and vary in skin colour from violet-red to yellow. The flesh, which is the edible part of the fruit, is white and contains small, edible, and crunchy seeds (Felger and Moser, 1976; Nerd *et al.*, 2002). Apple cactus fruits may be eaten fresh, dried, or can be made into a juice (Scheinvar, 1985).

Apple cactus fruits can offer commercial opportunities (Felger and Moser, 1976). However, at present, it is an unexplored, underutilized fruit (Morton, 1987; Inglese *et al.*, 2002).

The aim of this study was to investigate vegetative growth, development, storing ability of cuttings and grafting success of several apple cactus species introduced in a hyper-arid desert.

Materials and methods

Plant material: Cuttings from four *Cereus* species were obtained from private nurseries of California, USA. The introduced species were *C. hexagonus*, *C. pachanoi*, *C. peruvianus* and *C. validus*. The subspecies *C. peruvianus monstrose* was also introduced. Forty cuttings with 30 cm length from each species were used for propagation. Forty more cuttings of *C. peruvianus* and *C. peruvianus monstrose* were used in the storage experiment.

Cutting healing and storage: Thirty scions of each of *C. hexagonus*, *C. pachanoi*, *C. peruvianus*, *C. peruvianus monstrose*, *C. validus* and *C. pachanoi* were grafted on *C. pachanoi*. Cuttings were allowed to heal in a dry area at 30°C for ten days. Other cuttings of *C. peruvianus* and *C. peruvianus monstrose* were stored at 35°C up to eight months.

Propagation by cuttings: Pots (25 cm in diameter) were filled to about one-third full of potting mix consists of 1 part peat moss: 2 parts sand. Each cutting was planted in the center of a pot. Pots were completed to two-third full with the potting mix. Pots were watered and kept in the greenhouse at 27°C.

Propagation by grafting: Plants of *C. hexagonus*, *C. peruvianus*, *C. peruvianus monstrose*, *C. validus* and *C. pachanoi*, grown in 25 cm diameter pots, were used as scions. *C. pachanoi* plants grown in 25 cm diameter pots were used as rootstocks. The diameter of the stems of *C. hexagonus*, *C. pachanoi*, *C. peruvianus*, *C. peruvianus monstrose* and *C. pachanoi* plants was 9-12 cm. However the diameter of the stems of *C. validus* plants was 5 cm. With a sharp sterile knife, the top of the rootstocks was cut off 20 cm above the soil surface. The bottom of the scion plants was cut off 15 cm from the top. The scions and rootstocks

were joined together by lining up the two cylindrical parts and gently rotated to squeeze out any air bubbles. Two rubber bands of appropriate size were affixed over the scion and under the bottom of the pot. Rubbers could exert a steady pressure on the scion, pressing it against the stock to support the graft while the cut edges heal. The two rubber bands were placed over the scion at 90 degrees from each other, in order to prevent the scion from shifting. The grafts were supported with stakes, then kept in the greenhouse. The rubber bands were removed after two months of grafting.

Orchard location: The orchard was located in Al-Ain desert, United Arab Emirates (UAE), characterized with high temperatures and rare rainfall. Maximum temperature reaches 49°C during the summer and average annual rainfall is 77mm. Soil and irrigation water samples from the orchard were taken to determine salinity.

Transplanting: In the fall (15th September), plants propagated by cuttings were taken from the greenhouse to the shade for ten days acclimatization. The plants were then transplanted into the orchard. Hole was dug about 15 cm wider than the container and a couple inches deeper. The plant was slipped carefully out of its container. Heavy gloves and 40 cm forceps were used to avoid injuring the technicians or plants. The plant was placed into the hole and soil was firmed lightly around.

Irrigation and fertilization: The source of irrigation is the underground aquifer. Drip irrigation system was used in the orchard. Two liters of water was added per plant during two hours every two days. Fertilizer 12:4:24 (150g per plant) was applied one month after transplanting into orchard, then every two months during the growing season.

Data collection and analysis: Data were collected in two successive seasons (2001/2002 and 2002/2003) on plant survival, stem length and diameter and sprout or lateral branch development during the growing season (October – May). Other observations on growth behaviour were recorded. In storage experiment, each cutting was weighed at the beginning and every month during the storage period. In grafting experiment the healing and success of grafts was observed.

Completely randomised design was used for statistical analysis and mean comparisons were made using Duncan's Multiple Range test at 5% significant level (Duncan, 1955).

Results and discussion

Four apple cactus species were introduced into hyper-arid desert in the UAE. Orchard soil found to be sandy with 2200 ppm salinity. Salt concentration in the irrigation water ranged from 1800 to 2000 ppm.

Cuttings of the introduced *Cereus* species were allowed to dry in a warm, dry area for ten days to permit the cut surface to heal and develop callus. The callus helps prevent rotting during propagation (Hartmann *et al.*, 2001).

The introduced species grew in the hyper-arid desert successfully except *C. validus* that was eliminated during the first summer. All the plants of *C. peruvianus* and *C. peruvianus monstrose* survived in the new environment.

The main stem of *C. peruvianus* showed 9.2 cm increase in height (Fig. 1) and 0.9 cm increase in diameter per month (Fig. 2). Five sprouts developed per plant (Figs. 3 and 4). *C. peruvianus*, found in southeastern coast of South America, has already attracted attention as a potential fruit-crop (Backeberg, 1984). The fruit is smooth and spineless and varies from yellow to deep red (Weiss *et al.*, 1993). *C. peruvianus* was found to be very promising fruiting cactus (Morton, 1987; Inglese *et al.*, 2002).

C. peruvianus cuttings survived storage up to eight months. Cuttings lost about 50% of the original weight at the end of the storage period (Fig. 5). Horizontal position of the cuttings during storage encouraged the development of lateral branches (Fig. 6). Lateral branching averaged at four branches per cutting.

C. peruvianus monstrose cuttings did not survive more than three months of storage (Fig. 5). In the field, the main stem of *C. peruvianus monstrose* increased 10.2 cm in length and 1.1 cm in diameter per month (Figs. 1 and 2) and four sprouts developed per plant. *C. peruvianus monstrose* exhibited dramatic expansion and contraction of the stem as water availability changed (Fig. 7). Such mechanism enables the stem to conserve water and survive in dry, hot conditions (Wallace and Gibson, 2002).

Over millions of years, through natural selection, only the most adapted species survived in desert environment (John, 2001).

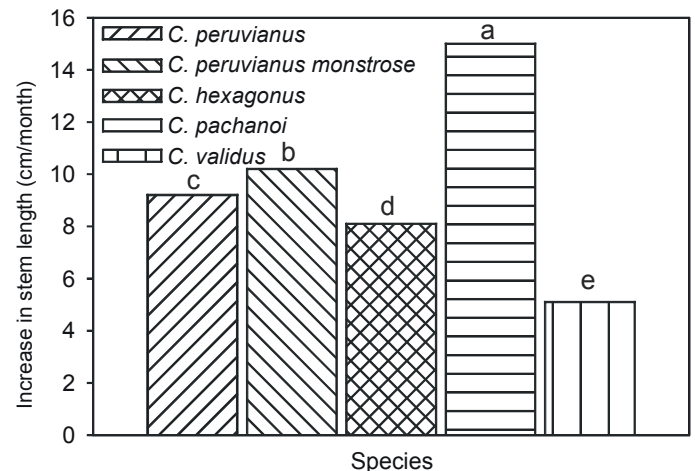


Fig. 1. Rate of the increase in main stem length of the introduced *Cereus* species. Columns labeled with the same letter are not significantly different ($P>0.05$).

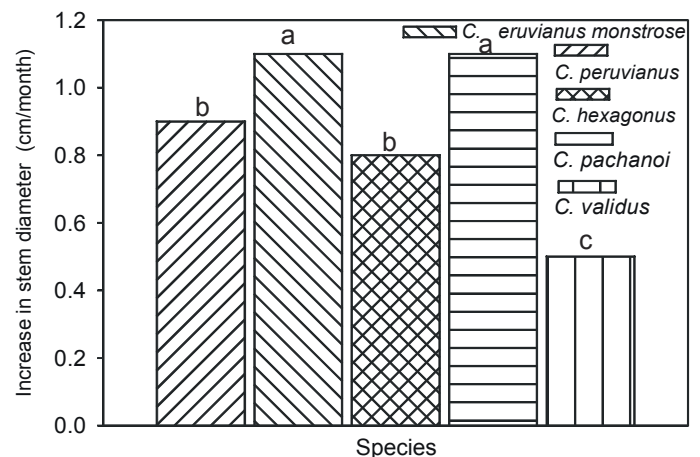


Fig. 2. Rate of the increase in main stem diameter of the introduced *Cereus* species. Columns labeled with the same letter are not significantly different ($P>0.05$).

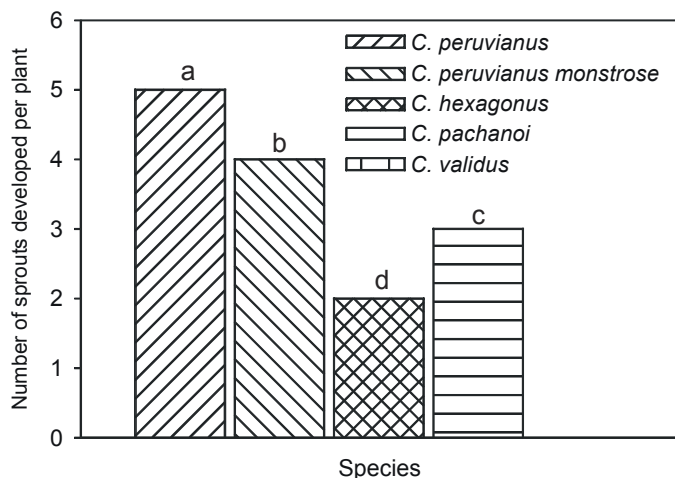


Fig. 3. Average number of the developed sprouts per plant during the first two seasons. Columns labeled with the same letter are not significantly different ($P>0.05$).

Generally, the family of Cactaceae, contains many plants that are highly adaptable to a new environment and able to tolerate drought, heat and saline soil. Apple cactus, as a member in the family Cactaceae has devolved to be well adapted to extremely xeric conditions (Mauseth, 2000; John, 2001). The pathway of photosynthesis in *Cereus* is the crassulacean acid metabolism in which stomata open at night (when evaporation rates are usually lower) and are usually closed during the day. The CO_2 is converted to an acid and stored during the night. During the day, the acid is broken down and the CO_2 is released to RUBISCO for photosynthesis. When conditions are extremely arid, *Cereus* plants can just leave their stomata closed night and day. Oxygen given off in photosynthesis is used for respiration and CO_2 given off in respiration is used for photosynthesis (Winter and Smith, 1996). Importance of crassulacean acid metabolism species increases in the face of expansion of desertification around the world (Cushman and Borland, 2002).

C. hexagonus is another introduced *Cereus* species with 73% of survival in the new arid environment. The main stem growth rate of *C. hexagonus* was 8.1 and 0.8 cm/month in height and diameter, respectively (Figs. 1 and 2). Each *C. hexagonus* plant

developed two sprouts during the first two seasons (Fig. 3). *C. hexagonus* is known to give ovoid red fruits with soft and juicy, white to pinkish pulp and numerous edible small black seeds. *C. hexagonus* was originated in Brazil (Anderson, 2001).

C. validus grew 5.1 cm in height and 0.5 cm in diameter per month during the first season (Figs. 1 and 2). However, it could not survive the high temperature during the summer months. All plants were dried and finally died during the first season.

All *C. pachanoi* plants survived the new environment. *C. pachanoi* grew very fast, averaging up to a fifteen centimeter a month of new growth (Fig. 1). Its stem diameter increased 1.1 cm per month (Fig. 2). Three sprouts developed per plant during the first two seasons (Fig. 3). *C. pachanoi* was introduced as a rootstock for grafting other species. *C. pachanoi* is popular as grafting stock for smaller, slower growing cacti (Ostolaza, 1984).

C. peruvianus, *C. peruvianus monstrose* and *Cereus hexagonus* united with *C. pachanoi* to form grafts with the success of 80, 53 and 86.5%, respectively. *C. validus*, however, failed completely to unite with *C. Pachanoi* (Fig. 8). This failure to form grafts may

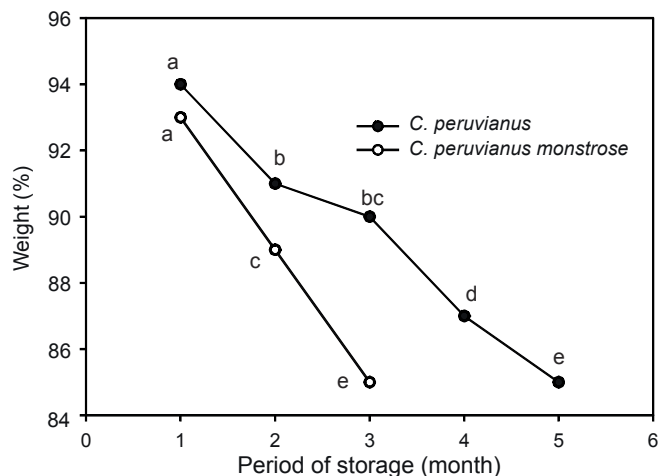


Fig. 5. Effect of the storage period on weight of *C. peruvianus* and *C. peruvianus monstrose* cuttings. Values labeled with the same letter are not significantly different ($P>0.05$).

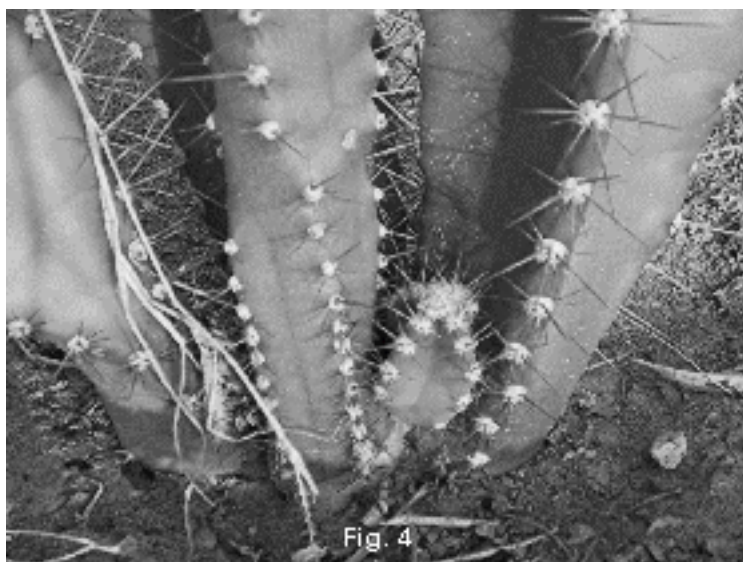


Fig. 4

Fig. 4. Sprouts were ramified from the base of the main stem of *C. peruvianus*.

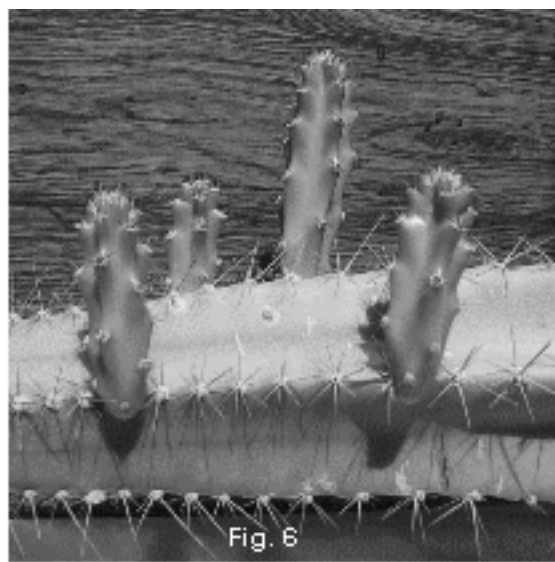


Fig. 6

Fig. 6. Horizontal position of *C. peruvianus* cuttings during storage encouraged the development of lateral branches.

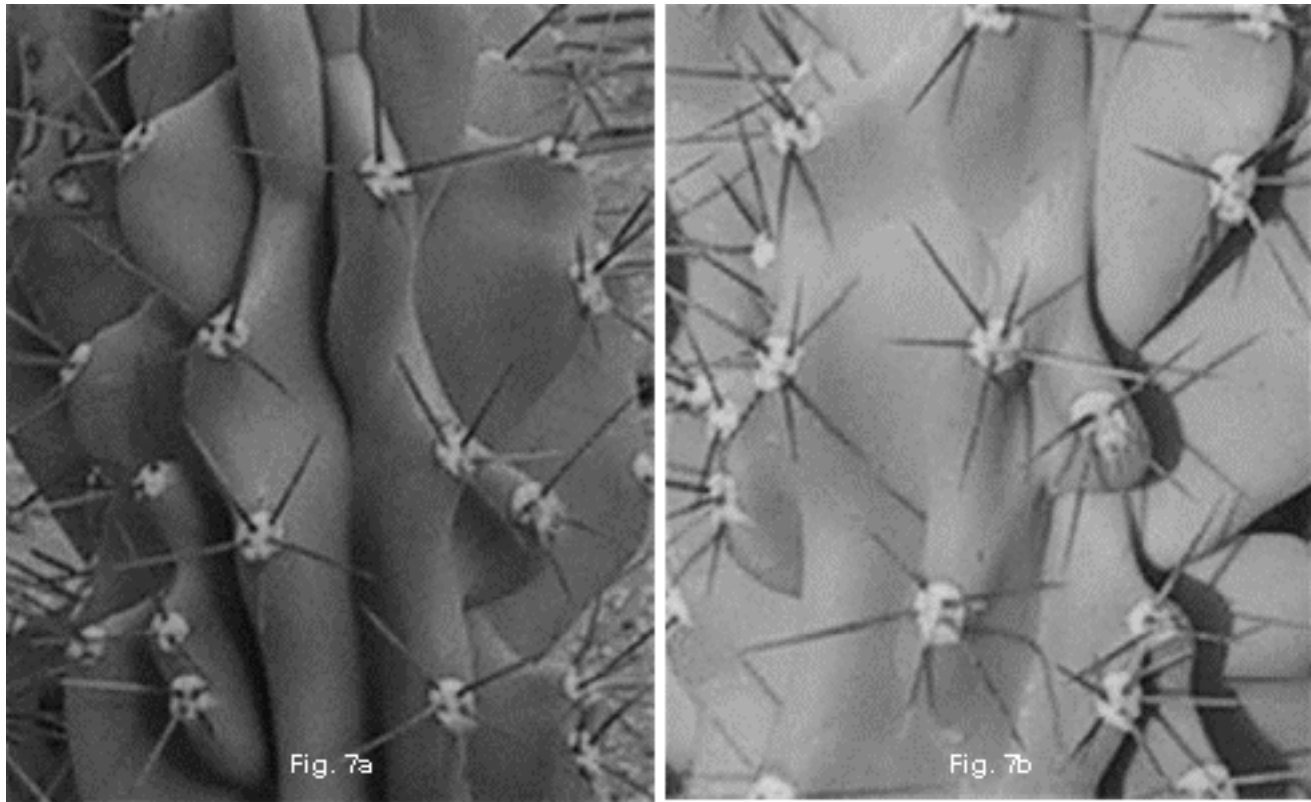


Fig. 7. Dramatic contraction (A) and expansion (B) of *C. peruvianus* monstrose stem as water availability changes.

be due to the incompatibility or the difference in the diameter between the scion and the rootstock. Incompatibility between the scion and the rootstock affects the healing, and could ruin the graft. The difference in diameter between the scion and the rootstock prevent meeting the cambial layers of the scion and stock resulting failure of healing. The risk is smaller if the scion and the rootstock are about the same diameter (Hartmann *et al.*, 2001). However, self grafted *C. Pachanoi* healed with 93% of successful grafts.

Grafting in cactus is really best used as a technique for saving a dying cactus from certain death, speeding up breeding programs or growing less hardy species. Often in cactus genetic improvement, hybridization, and clonal selection programs, the researchers need a more rapid method to prove or disprove the

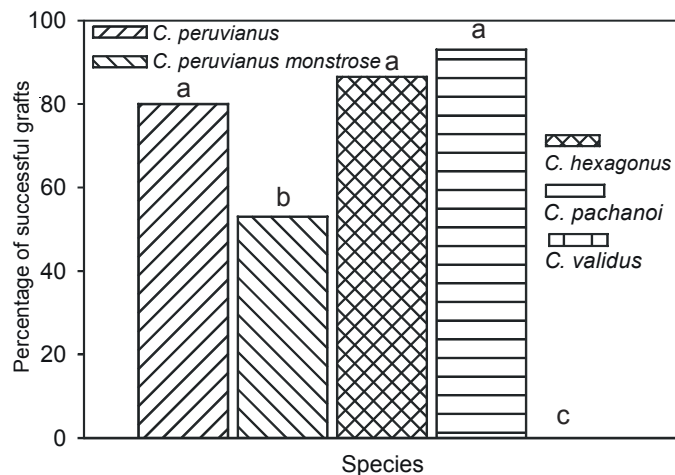


Fig. 8. Percentage of succeeded grafts of different *Cereus* species on *Cereus pachanoi*. Values labeled with the same letter are not significantly different ($P > 0.05$).

merits of a fruiting clone. To speed the evaluation process for fruit production and to adapt certain clones to local conditions, grafting was done onto mature plants in the ground (Huffman, 2003). A grafted cactus can grow faster, flower sooner and often be used with cactus species having sensitive soil requirements (Hartmann *et al.*, 2001).

The hyper-arid region has limited renewable freshwater supplies (Wilhite, 2000). So, a large portion of the hyper-arid region is desert, the majority of which is uninhabitable because of lacking the biological production (Al Alawi and Abdulrazzak, 1993). It is vital that the kind of agriculture practiced in hyper-arid region should use as little water as possible. In addition, agricultural activities should produce materials that can have economic potential. Apple cactus species *C. peruvianus* and the subspecies *C. peruvianus monstrose* were the most promising in the new hyper-arid environment in terms of adaptability and healthy growth. Apple cactus may give the inhabitants of the hyper-arid and marginal lands a way of making a living.

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