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Rehabilitation of degraded coastal Mediterranean rangelands using *Panicum turgidum* Forssk.

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Panicum turgidum Forssk. is a widely distributed species in the Egyptian desert. This species meets all criteria for a multipurpose plant and is capable of being used in the rehabilitation of degraded ecosystems. The paper presents the most suitable methods for the propagation of and testing the possibility and capacity of germination and growth of different populations of *Panicum turgidum*. Besides investigating the socioeconomic value of this species through the documentation and survey of its traditional uses, the study illustrates the importance of *P. turgidum* for the local inhabitants as a very important fodder plant, for both domestic and wild animals. The main benefit from propagating this plant is an increase in grazing potentialities and reduction of the use of artificial feed. The results of the present study shows that individuals propagated by direct seed sowing attained the highest values of growth parameters, followed by those propagated by rhizomes, then those propagated by seedlings. The most suitable method for propagating it, in this region, is by grains and the best time is the first week of June. The results also show that the *P. turgidum* populations collected from the eastern desert attained the highest germination percentage and maximum values of growth parameters upon cultivation. Thus, eastern desert populations are recommended as a good source of grains for rehabilitation programs.

Keywords: Mediterranean, desert, rehabilitation, *Panicum turgidum*, germination, growth, grazing

Introduction

Besides biological erosion, arid lands are exposed to erosion of indigenous knowledge as well as of traditional cultivars and rangeland species. Erosion of the traditional knowledge adds to the problems of biodiversity conservation in arid lands. The erosion of biodiversity and indigenous knowledge has many implications for biodiversity conservation efforts. Without an adequate understanding of their own natural resources, future rural communities and individuals will fail to maintain these resources (GRAINGER 2003, SOLH et al. 2003).

Panicum turgidum Forssk. (Poaceae) is one of the widely distributed and most drought-resistant grasses of the Egyptian desert (MIGAHID and EL SHOURBAGY 1961a). According

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to TÄCKHOLM (1974), this species is widely distributed in all phytogeographical regions of Egypt except the western Mediterranean coastal desert. It is a tussock forming sand dwelling perennial grass, dominating in many parts of the internal deserts of Egypt and growing prosperously under severe desert conditions (MIGAHID and EL SHOURBAGY 1961a). The success and wide distribution of this plant indicates its ability to tolerate certain unfavourable conditions (ISMAIL and SEED 1983).

P. turgidum is a remarkable drought-resistant species. Established plants may survive for several years without rain (DRAR 1936). It appears to be tolerant to fairly high salinity stress. Therefore, it is a good species for stabilizing loose soil (EL SHOURBAGY 1958). Since many native grasses of the coastal strip of Egypt are spring growers, the summer growth of *P. turgidum* may make this species suitable as complementary forage for the deteriorated lands of the western coastal desert of Egypt. *P. turgidum* has the merit of being resistant to drought and also an effective sand-binding xerophyte (MIGAHID and EL SHOURBAGY 1961a). Wind-borne sand usually accumulates around the bushes of *P. turgidum* forming isolated mounds that gradually enlarge and eventually coalesce and form sandy patches that cover the original gravely or stony bed (KASSAS and IMAM 1959, ZAHRAN and WILLIS 1992). Thus, it is one of the best grasses to protect the soil against transportation by both wind and water (MIGAHID and EL SHOURBAGY 1961a). Accordingly, *P. turgidum* is usually used in many rehabilitation programmes in arid regions (DOUGRAMEJI and KAUL 1972, HADJEJ et al. 1991, AHMED et al. 1994, SINHA 1997).The present study aims at: **a)** investigating the socioeconomic value of this species through the documentation and survey of its traditional uses and the relationships between it and the local inhabitants; **b)** detecting the most suitable methods for its propagation; and **c)** testing the possibility and practicability of and capacity for germination and growth of different populations of this species in degraded arid ecosystems of the north western Mediterranean coastal desert of Egypt.

Materials and methods

Collection of specimens

Fresh specimens and seeds of *P. turgidum* were collected from 4 sites (Tab. 1), selected to represent a wide variety of habitats within the range of its distribution in the Eastern Desert; Wady El-Natrun; and Sinai. According to TÄCKHOLM (1974) these sampling sites are located in four different phytogeographical regions; the Eastern Desert region, Mediter-

Tab. 1. Population number, location and sites description

Population Number	Site description	Location
I	Spika, sand dune	North Sinai
II	El-Qaa plain (15 Km from El-Tur city), coastal plain, drainage lines of the plain covered with alluvial deposits	South Sinai Gulf of Suez
III	Wadi Kid, Khashm El-Fakh (Nabq protected area), drainage lines of the wadi bed covered with alluvial deposits	South Sinai Gulf of Aqaba
IV	East of Um-Risha Lake, sandy plain, with fine deep sand deposits	Wady El-Natrun

ranean region (including north Sinai), Oases of the Western Desert (Wady El-Natrun), and Sinai proper (Fig. 1).

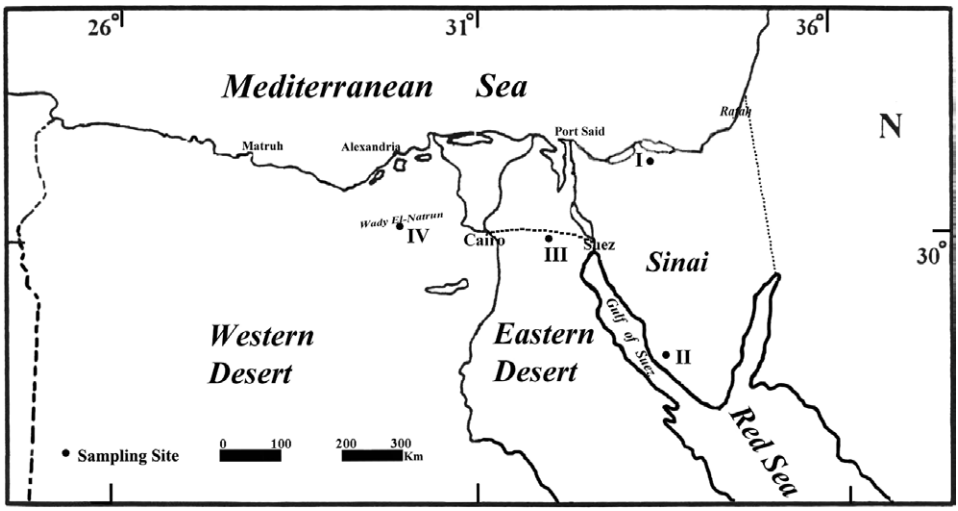

Fig. 1. Map of northern Egypt showing the locations of the sampling sites from which *P. turgidum* populations were collected

Socioeconomic evaluation

The social survey method was used for collecting indigenous knowledge about the studied species. Data were collected from the local inhabitants of the sampling area through a questionnaire together with field observations. The questionnaire was prepared, tested, and amended to fulfill the objectives of the present study. The questionnaire covered the following items: (1) uses of *P. turgidum*; (2) the need for propagating this species; and (3) conservation measures. It was decided that the study should cover a representative sample of households from each sampling site. The household was considered as the unit of study. From 5–8 households were interviewed for each sampling site whenever possible.

Experiment 1

Grains of Population IV (collected from a population with adequate quantity of grains) were used in this experiment to detect the most suitable method for propagation in the experimental study area at El-Omayed Biosphere Reserve (83 km west of Alexandria).

***Propagation by seedlings (transplantation)*:** From 10–15 grains were planted in plastic bags (30 plastic bags were used). The plastic bags were filled with equal amount of air-dried sandy soil obtained from the experimental study area. All the plastic bags were irrigated with the same amount of water in such a way that the soil was maintained constantly moist (Tab. 2). The plastic bags were left in the greenhouse of the botanical garden, Faculty of Science-Alexandria University for two months from 1st February to 31st March 2002, then the seedling were transplanted in the experimental study area. The seedling were

Tab. 2. Amount of water used in experiment I

Period	Amount of precipitation (mL)
(A) Propagation by seedlings	
1st month	1000
2nd month	1000
3rd month	6000
4th month	4000
(B) Propagation by rhizome	
1st month	3000
2nd month	3000
3rd month	4000
4th month	2000
(C) Propagation by seeds	
1st month	4000
2nd month	4000
3rd month	2000
4th month	2000

Tab. 3. Amount of water used in experiment II

Period		Amount of water (mL/ per plastic bag)
(A) During germination	1st week	100
	2nd week	100
	3rd week	50
	4th week	50
	5th week	50
	6th week	50
	7th week	25
	8th week	25
(B) During propagation	1st month	4000
	2nd month	4000
	3rd month	2000
	4th month	2000
	5th month	2000

transplanted taking into account that the distance between neighbouring plants was sufficient to provide room for proper root development and to secure firm hold of the soil by the root. A month after transplantation, transplants were irrigated twice a week, then weekly (Tab. 3).

Propagation by direct sowing of grains: Adequate amount of grains were sown directly in the soil in the first week of June. The soil was irrigated three times weekly for 8 weeks, and then irrigated weekly for about two months (Tab. 3). The experiment extended from 31st May to 30th September 2002. Observations included measurement of plant vigour and growth parameters estimated after four months.

Propagation by rhizomes: Some rhizomes of the individuals grown in the experimental area were taken and planted in a neighbouring plot on 31st May. The soil was irrigated three times weekly for 8 weeks, and then irrigated weekly for about two months (Tab. 3). The experiment extended from 31st May to 30th September 2002. Observations included measurement of plant vigour and growth parameters estimated after four months.

Experiment 2

Grains of four *P. turgidum* populations (sites I, II, III, and IV) representing four phytogeographical regions, different habitats and present in sufficient quantity were used in this experiment to determine the possibility and the practicability of germination and propagation of the different populations of the studied species.

To test the germination capacity of the studied populations, grains were sown in plastic bags (10–15 grain per bag), filled with equal amount of air-dried sandy soil obtained from

the experiment area. Fifteen bags were planted for each of the four studied populations. All the plastic bags were irrigated with the same amount of water in such a way that the soil was maintained constantly moist (Tab. 2). The plastic bags were left in the greenhouse. Germination was observed for a period of eight weeks. The method that gave the best results in experiment 2 was employed in comparing the growth capacity of the cultivated individuals of the studied populations. Plant vigour and growth parameters employed in this investigation are as follows: mean length (cm), mean diameter (cm), mean number of culms, mean number of fruiting culms and mean volume (dm^3) per plant individual. The volume of the plant is determined using formula of a solid cylinder that appears to give the best fit to the natural shape of the plant (LUDWIG et al. 1975 and MOLINERO, 1983):

$$\text{Volume} = \pi \times R^2 \times H$$

Where R, is the radius obtained by averaging the maximum crown width with the diameter at right angles and halving it; and H is the height of the plant.

Data analysis

The significance of variation in the growth parameters (length, diameter of the plant, plant volume, number of culms and number of fruiting culms) among the cultivated populations was assessed using one-way ANOVA test.

Results

Socioeconomic evaluation

All the local inhabitants questioned considered *P. turgidum* a very important fodder plant, for both domestic (goats, sheep, camels, and donkeys) and wild animals (gazelle and hare), for even in dry conditions it provides food for camels and donkeys as indicated by 48.6% of the local inhabitants (Tab. 4). The grains are eaten by sparrows and domesticated hens. In its flourishing time it is preferred to other plants by all animals, as indicated by 15.7% of the questioned local inhabitants, by camels as indicated by 35.7% of the questioned local inhabitants, while 25.7% of them indicated that the gazelles prefer it to other plants. The questioned local inhabitants (7.1%) said that they clip the plant, dry it and store it to use it in time of shortage in natural fodder. On the other hand, the young green parts of the plant provide human food, 64.3% of the local inhabitants indicated that they eat the young green parts of the plant, calling it *shamalikh*. The dry aerial parts are used in making desert shelters, and in making fences around their shelters as indicated by 7.1% of the questioned local inhabitants. The local inhabitants indicated also that they use the dry parts as fuel. The questioned local inhabitants (7.1%) indicated that they use an infusion of the plant in healing wounds, and that they chew the plant for treating toothache.

About 48.6% of the questioned local inhabitant recognsied the need for the propagation of the plant, but they added that water is limiting factor. However, 51.4% of the respondents indicated that there was no need for propagating the plant as it was growing naturally. The idea of propagating the plant through any proposed agricultural project was supported by 42.9% of the respondents, while the rest (34.3%) indicated that no one had thought of that before. About 11.4% of the respondents indicated that they had endeavoured to propagate

Tab. 4. Socioeconomic evaluation of *Panicum turgidum*

Subject	Inquiry	Answer	Questioned local inhabitants (%)
Uses of P. turgidum		**A. Grazing**	
	The grazing value of the plant different parts	• Green aerial parts grazed by sheep, goats, camels and donkeys	100
		• Dry aerial parts grazed by camels and donkeys	48.6
		• Grains grazed by sparrows and chickens	57.7
	The season of maximum grazing of the plant	• The season of maximum grazing is after the plant flourishes	100
	Preference of the plant by certain animals during flourishing time	• For all animals	15.7
		• Camels	35.7
		• Donkeys	7.1
		• Gazelles	25.7
		• Hare	12.9
		B. Other uses	
	Young green shoots (shamalikh)	• Edible	64.3
		• In cosmetic purposes	32.9
	Dry stiff shoots	• Used as tool for making handicrafts	15.7
		• Used as part of an ornamental piece (kushkash of gold)	11.4
		• Used in making desert shelters	7.1
		• Used in making fences and windbreaks	31.4
		• Used as firewood	25.7
	Medicinal value	• In healing wounds	7.1
		• In treating toothache	5.7
	Other importance	• Clipped dried and stored as fodder during the season of low natural fodder	7.1
		• Considered as indicator of soil suitability for cultivation of crops	12.9

Tab. 4. – continued

Subject	Inquiry	Answer	Questioned local inhabitants (%)
Propagation Needs	**Needs for propagating the plant**	• No need, it is growing naturally	51.4
		• There is need, but sufficient water should be available	27.1
		• There is a need	21.4
	Willingness to propagate the plant through any proposed projects Of agricultural	• No will, it is growing naturally	22.9
		• No, one has thought of that before	34.3
		• There is a will for propagating the plant, if sufficient water is available	42.9
	Pervious trials for propagating the plant	• There is trials	11.4
		• No trials	88.6
	Expected benefits recurring to the local communities in case of propagating the plant	• Increase in the fertility of the land	14.3
		• Increase in the grazing potentialities and decrease in the need for other fodders	81.4
		• Fixation of soil	4.3
Conservation Measures	**Efforts needed to conserve the plant**	• Controlling the grazing of the plant	12.9
		• Controlling the uprooting of the plant	18.6
		• Supplying sufficient water only	38.6
		• Supplying sufficient water and controlling grazing	14.3
		• Supplying sufficient water and controlling plant uprooting	15.7
	If any efforts have been practiced before to conserve the plant in the area	• No	82.9
		• Yes, uprooting is prohibited	17.1

the plant, while the rest of them indicated that they have never thought of this before. Most of the respondents (81.4%) considered that the main benefit of propagating the plant would be the increase in grazing potentialities and the decrease in the use of artificial feed. However, 14.3% indicated that the benefit would be the increase in the soil fertility as they consider the plant as an indicator for the suitability of the soil for farming some crops, especially watermelon.

Most of the respondents adopted the idea that the availability of water in sufficient quantities was a priority requirement for conserving the plants. However, about 34.3% of them added that controlling the uprooting of the plant should be considered, and 27.1% indicated that controlling the grazing of the plant was required. Most of the respondents (82.9%) have never followed any measures or done any efforts to conserve the studied species. Nevertheless, the rest of them indicated that they have followed a local regulation prohibiting the uprooting of this plant.

Propagation experiments

In the first experiment individuals propagated by direct seed sowing attained the highest values (Fig. 2). Grains of the population III attained the maximum percentage of germination (73.3 ± 6.1%), followed by population I (70.7 ± 5.3%), Population IV (63.97 ± 4.9%), then population II (56.4 ± 3.7%) (Fig. 3).

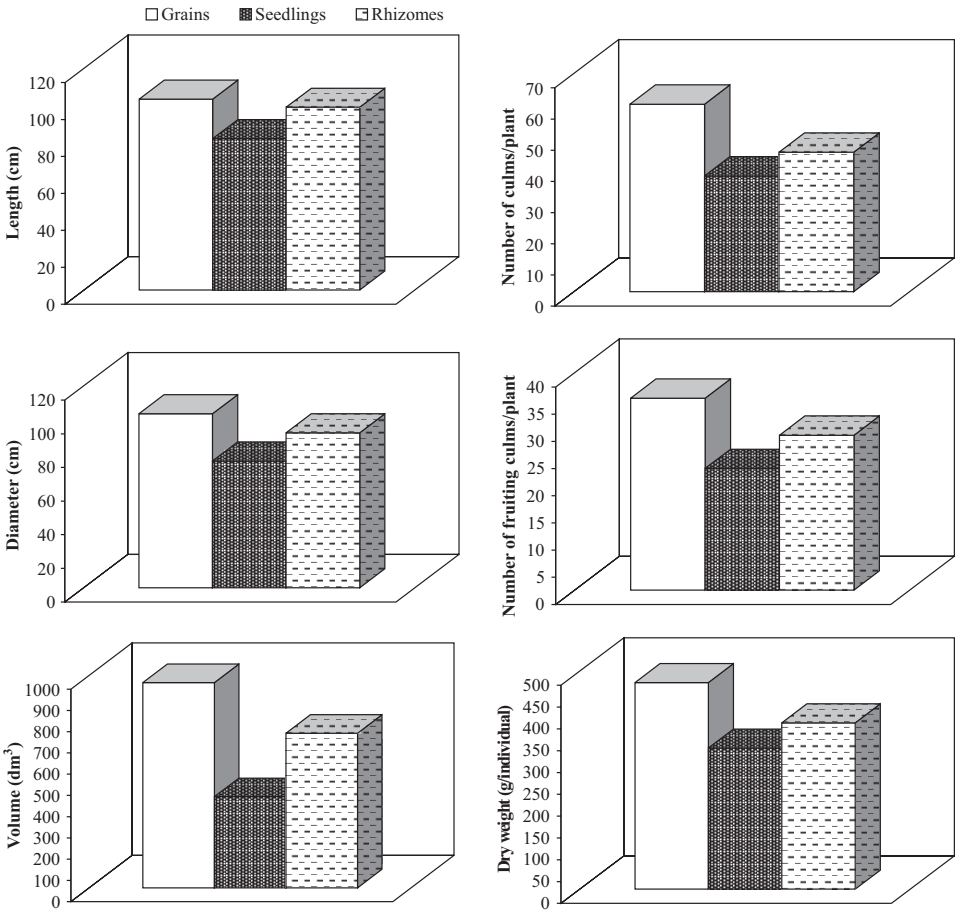

Fig. 2. Length, diameter and volume, number of culms, number of fruiting culms and dry weight of the cultivated *P. turgidum* individuals propagated by grains, seedlings and rhizomes

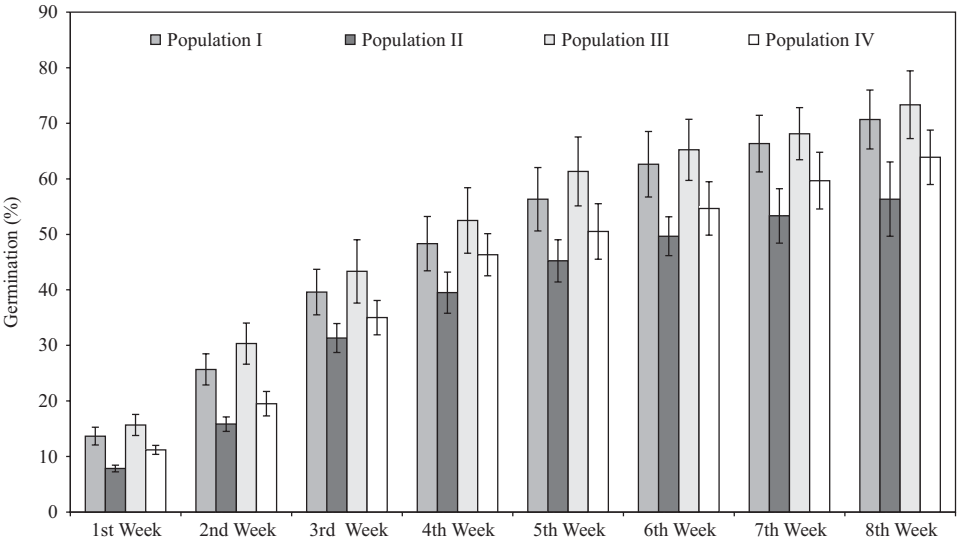

Fig. 3. Germination percentage of *P. turgidum* during the period from 1st May to 31st June 2003

Based on the results of the first experiment the propagation by grains method was conducted on the studied populations (experiment 2). The results of the investigated growth parameters exhibited by the cultivated individuals during the period from 1st June to 1st October, showed that Population III attained the maximum growth, followed by Population II, Population I and Population IV (Figs. 4 a, b, c, d).

Individuals of Population I attained the maximum mean length (114.9 ± 4.6 cm), followed by Population III (110.8 ± 8.9 cm), Population II (105.7 ± 3.1 cm), then Population IV (102.8 ± 3.4 cm). Individuals of Population III attained the maximum mean diameter (115.76 ± 10.36 cm), followed by Population II (114.1 ± 4.6 cm), Population I (110.9 ± 6.4 cm), then population IV (110.2 ± 4.5 cm). The individuals of Population III attained the maximum mean volume (1191.9 ± 216.0 dm^3), followed by Population I (1122.2 ± 123.4 dm^3), Population II (1095.2 ± 108.0 dm^3), then Population IV (983.5 ± 79.0 dm^3). The individuals of Population III attained the maximum mean number of culms per plant (90.4 ± 7.2), followed by Population II (89.8 ± 7.3), Population I (83.6 ± 6.1), then Population IV (74.4 ± 4.2). The individuals of Population III attained the maximum mean number of fruiting culms per plant (36.0 ± 3.5), followed by Population II (34.8 ± 5.7), Population I (32.6 ± 4.3), then Population IV (30.2 ± 3.8). Results of one way-ANOVA (Tab. 5) applied to the growth parameters, of the cultivated *P. turgidum* populations indicated that the variation between the studied four populations was insignificant.

Discussion

Panicum turgidum is an effective sand-binding xerophytic grass that may dominate sandy deserts and sandy accumulations, it also grows on mixed sand and gravel deposits, but is uncommon on limestone detritus. *P turgidum* is a bush-forming sand-dwelling perennial grass that may acquire an evergreen habit especially in favourable conditions. Under

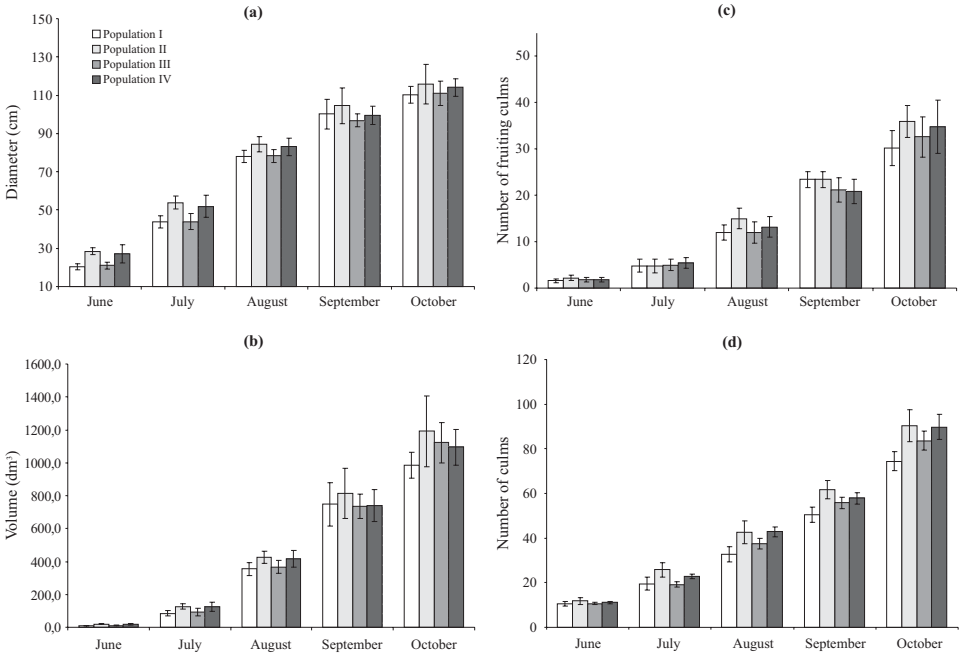

Fig. 4. Mean diameter (cm) **(a)**, mean volume (dm^3) **(b)**, mean number of culms per cultivated individual **(c)** and mean number of fruiting culms per cultivated individual of the studied *P. turgidum* populations **(d)** during the period 1st June to 1st October 2003.

Tab. 5. F-value of one way-ANOVA test of significance of variation in the growth parameters among the cultivated *P. turgidum* populations during the period from 1st June to 1st October 2003. = $P < 0.05$, = $P < 0.01$, and = $P < 0.001$.

Character	Month				
	June	**July**	**August**	**September**	**October**
Length in cm	0.51	0.39	0.12	0.73	0.95
Diameter in cm	2.06	1.57	0.73	0.23	0.15
Volume in dm^3	2.4	0.99	0.68	0.1	0.38
Number of fruiting culms	0.26	0.05	0.45	0.39	0.34

less favourable conditions it may have a deciduous growth-form, remaining and looking dead for a prolonged period of time. However, the plant regains its green habit after rainfall (ZAHRAN and WILLIS 1992). The plant flourishes and produces new leaves by the end of spring and advent of summer. It flowers from April to June (BATANOUNY 1981)

Policies on land management strongly promote the use of native plants in restoration, rehabilitation and other revegetation projects. Maintaining the diverse native plant communities on a long-term basis is an essential part of preserving ecosystem health and productivity, and the introduction of non-natives is clearly contrary to this goal. Native restora-

tion is a quickly expanding field; through careful planning, collection, and production it is possible to meet revegetation needs with appropriate native species (BLM 1996).

Local communities habitually deal with a complex system of grazing and farming on marginal lands with few external inputs. They have the best knowledge about local species, and local biodiversity can continue to support their communities. This knowledge (ethnobiology) is seldom fully appreciated by either developers or policy makers. However, it should be harnessed to support implementation of the Convention on Biological Diversity (SOLH et al. 2003, MCNEELY 2003). Recently, attention has been focused not only on studying how plants are used, but also on how they are perceived and managed and on the reciprocal relationships between human societies and the plants on which they depend. Outside Europe and America, academic research into indigenous plant knowledge has become widespread. In Africa, traditional rangeland management and the uses of wild and cultivated plants have received academic scrutiny (COTTON 1997). Species with potential to be used either for fodder production or in rehabilitation and restoration programs have to be prioritized through collection of indigenous knowledge, discussion with Bedouins and local inhabitants and published.

The results of the present study showed that the local inhabitants consider *P. turgidum* as one of the most important grazing plants. It is grazed by their domesticated animals (sheep, goats, camels and donkeys). In its flourishing time it is preferred over other plant species. Even in dry conditions it provides source of food for camels and donkeys. These findings agree with those of TÄCKHOLM et al. (1941), ISMAIL and SEED (1983), TURNER (1983), BOULOS (1985), LE HOUÉROU(1985), AYYAD (1995). Moreover, local inhabitants indicated the preference of *P. turgidum* by some of the important and endangered wild animal species (e.g. gazelles and hare), which adds to the value of this species and focuses on the necessity of conserving and propagating it. This agrees with TURNER (1983), MOHAMED et al. (1991), AL-HAZMI and GHANDOUR (1992) who report that *P. turgidum* is a preferred diet for the gazelles, addax, oryx and hares. The present investigation indicated that the local inhabitants usually use *P. turgidum* dry shoots in making fences around their shelters and cultivated areas; they also use the dry plant as a fire starter. These findings agree with CHEVALIER (1934), TÄCKHOLM et al. (1941), AYYAD (1998).

Concerning the medicinal value of *P. turgidum*, local inhabitants may chew the plant for treating toothache and use the extract of the plant in treating wounds. Similarly, MAIRE (1933), BOULOS (1983), TURNER (1983) reported that *P. turgidum* is used by local inhabitants in treating wounds and removing eye spots. In the present study the investigated local inhabitants indicated that they do not rely on *P. turgidum* as a source of human food. They eat only the young green parts of the plant, which they call *shamalikh*. This agrees with ZOHARY (1962) who stated that *P. turgidum* grains are not utilized in the Near East. Local communities of Western Sahara and the mountains of Central Sahara used to gather and sell the grains of this plant in markets (ZOHARY 1962, GAST 1969, HARLAN et al. 1989, SMITH 1992). They would usually grind it into meal and use it to make porridges or bake it into bread. Moreover, SMITH (1992) reported that *P. turgidum* is considered the most important wild species to the Tuareg, being not only the most abundant but also the first to ripen. The present study revealed also that dry and green stalks of *P. turgidum* are used by local inhabitants for making handicrafts, making ornamental pieces and in some ornamental purposes.

Local inhabitants may propagate the plant if sufficient water is available and believe that propagation of *P. turgidum* will increase the grazing potentialities and decrease the

needs for supplementary feed. The results of the socioeconomic investigation also showed that the local regulations of the communities living in the vicinity of the El-Zaranik protected area prohibit the uprooting of *P. turgidum*. On the other hand, in the rest of the investigated regions, the local inhabitants usually do not take measures to conserve the plant. This is mainly because of its grazing value and their beliefs concerning it as indicator of soil suitability for the cultivation of watermelon. This may be attributed to the association of mycorrhizae (vesicular-arbuscular type) with *P. turgidum* roots (KHALIEL 1989, SRIVASTAVA et al. 1997). Such association increases the availability of nutrients especially phosphates which leads to the increase of soil fertility (HOPKINS 1995, WILD 1996, NOBEL 1999). Moreover, the accumulation of the faecal remains of the grazing animals increases the fertility of the surrounding soils. Besides, *P. turgidum* bushes add to the fertility of the surrounding soils via accumulation of decayed litter and the increase of soil moisture. This may explain why local communities prefer to plant their crops near the studied species or to uproot it for cultivation purposes.

Panicum turgidum has already been successfully used in major reseeding programs and in programs of rehabilitation of degraded rangelands and for the stabilization of moving sand dunes to stop desert encroachment in similar ecosystems. It was also used successfully in the rehabilitation of the Thar Desert in India (SINHA 1997); saline west lands and sandy deserts of Pakistan (AHMED et al., 1994), reclamation of sand dunes in Iraq (DOUGRAMEJI and KAUL 1972), combating desert encroachment in Sudan (ANONYMOUS 1976) and in Mauritania (HADJEJ et al. 1991). The use of this species is further recommended by MIGAHID and EL SHOURBAGY (1961a), ZOHARY (1962), WILLIAMS and FARIAS (1972) in developing and rehabilitating impoverished rangelands. The use of *P. turgidum* as a sand binder has been described by MIGAHID and EL SHOURBAGY (1961a, b), LE HOUÉROU (1985), BOULOS (1989), AYYAD (1998), SINHA et al. (2002).

A study of germination requirements of the plants of potential for use in revegetation and rehabilitation of disturbed lands is of great priority to provide information as an aid to its use in these programs (FULBRIGHT et al. 1983). In the present study, the highest percentage of germination was attained by Population III (collected from Eastern desert, km 101, Cairo Suez-Road). This population was characterized by having the heaviest grains. On the other hand, population II (collected from south Sinai, 15 km from El-Tur city at El-Qaa plain) which was characterized by having the lightest grains attained the lowest percentage of germination. This finding is in agreement with WEAVER and CLEMENTS (1938), WINN (1985), HARPER (1981), SHALTOUT et al. (1989). They reported that seed size was considered one of the seed characteristics that may dictate some safe sites and vigorous population. The germinating capacity of seeds is intimately related to the vigour of the plants producing these seeds. Larger seeds posses more stored energy than smaller seeds, and this may affect the emergence, survival and establishment of seedlings. This in turn constitutes a key factor in the maintenance and recovery of vegetation cover (HARPER 1977, CHAMBERS et al. 1987). Population III attained also the highest values of most of the studied growth parameters, and proved to be the most vigorous, and hence could be considered promising for rehabilitation programs.

Knowledge of the most suitable method and time for propagating rehabilitation plant species is a key factor in the success of the rehabilitation of the degraded ecosystems. Results of the present study have revealed that propagation by sowing gave the highest yield, better than that by rhizomes or by transplantation (seedlings). This agrees with the finding

of AKBAR et al. (1996), who reported that the dry matter yield was higher after sowing than after stump planting of *P. turgidum* and other four arid land grasses. Besides, plants emerging from seeds were more vigorous than those arising from stumps. The findings of the present study disagree with those of KABIEL (2001), who reported that the productivity of *P. turgidum* propagated by rhizome is greater than that by seeds.

Propagation of *P. turgidum* in the western Mediterranean coastal region by rhizome seems to be inapplicable, as it is difficult to bring the rhizomes from their native habitats without being adversely affected. Moreover this method and the propagation by seedlings method are labour-intensive and less economic. On the other hand, the sowing method is economic and effective in terms of dry-matter yield.

The present study showed that the variation in yield-related characters (most discriminative characters in the cluster analysis) among the cultivated populations was insignificant. This indicates that the variation in these characters is environmentally induced. Variation in environmental conditions might produce genetically fixed morphological and physiological adaptation due to great possibilities of isolation of ecological populations of a species »ecotype«. A successful rehabilitation process is more likely to be achieved if knowledge of the best date for propagation of the selected plant is available. This knowledge should be based on information on the temperature requirement for the germination of the selected species and information on the seasonal temperature and moisture conditions of the area under investigation (ASHBY and HELLMERS 1955). The present study revealed that the best time for propagation of the plant in the western Mediterranean coastal region is in summer (June), as the temperature begins to increase. For maximum germination, *P. turgidum* requires a high temperature, ranging from 25 to 42 °C% (MIGAHID and EL SHOURBAGY 1961b, ISMAIL and SEED 1983, KABIEL 2001). Not only high temperature necessary for successful germination, but also an adequate water supply is required, a condition which does not prevail in the natural habitats supporting the species in the Egyptian deserts (BATANOUNY 1969). This explains why seedlings of the studied species are rarely met with in the natural habitat, consequently the reproduction and spreading of this species takes place mainly vegetatively. In the course of this study, all the results obtained showed decisively that *P. turgidum* can play an important role in the rehabilitation of the degraded arid ecosystems of Egypt.

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