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Short communication

Panicum turgidum, a potentially sustainable cattle feed alternative to maize for saline areas

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ABSTRACT

Salinity of soil and water has been a major impediment to plant growth and crop production worldwide, and a viable solution is not forthcoming, at least in the near future. One potential means for addressing this problem lies in cultivating plant species that are able to tolerate the adverse conditions prevailing in such situations. A search among halophytic plant species to find suitable fodder replacement for calves has been successful in identifying a local perennial grass, *Panicum turgidum*, with biomass yields of about 60,000 kg/ha/year (fresh weight) when grown in saline soil (EC 10–15 mS cm^{-1}) irrigated with brackish water (EC 10–12 mS cm^{-1}). When grown with a salt accumulator (*Suaeda fruticosa*) in adjacent rows and with frequent irrigation, this system may be sustainable in terms of soil salt balance, with little change in soil salinity detected. *Panicum* was used as a complete replacement for maize in a cattle feeding trial and resulted in equivalent growth and meat production. Implementation of this system should allow saline land and brackish water to be used for producing an economically beneficial feed crop.

1. Introduction

In many parts of the world urban expansion is encroaching into surrounding prime agricultural lands. At the same time, many regions have seen an increase in soil salinity due to heavy long-term irrigation practices and intense land utilization. This has resulted in growing pressure on arable land and good quality non-saline water and has greatly reduced crop productivity in many regions of the world, including many poor and developing nations. At the same time, there has been a substantial increase worldwide in livestock and meat/milk production. However, the availability of good quality animal forage is unable to meet the current demand. Therefore, an urgent need exists to find alternate methods to increase forage production.

The identification and development of salt tolerant fodder crops may help address the scarcity of good quality water in many arid agricultural regions of the world where vast reserves of saline and brackish water exist. Many halophytes are able to produce high biomass under saline conditions. Halophytes have long been known to be a valuable resource for utilizing saline lands and brackish water. Their potential as animal feed, however, has remained relatively unfulfilled. In the past few decades the effect of salt in drinking water and feed on animal health and meat quality/quantity has received scientific scrutiny (Wilson, 1966; Walker et al., 1971; Hopkins and Nicholson, 1999; Thomas et al., 2007) with limited success (Weston et al., 1970; Weston, 1996; Wilson and Kennedy, 1996; Norman et al., 2004). Scientists in various parts of the world have attempted to partially or completely replace regular fodder with a variety of halophytes. *Diplachne fusca* (Kallar grass, Malik et al., 1986) and *Distichlis spicata* (Yensen, 2006) can be cited as examples of potential halophytic grasses, but no integrated studies appear to have been done with either for use as cattle feed.

Halophytes that accumulate salt (accumulators) are generally unsuitable as fodder crops due to high salt content, and therefore a plant that does not take up salt (salt excluder) is preferred as a feed crop. However, salt excluders are associated with increases in soil salinity when irrigated with brackish water. Under these conditions a combination of both a salt excluder, which is fed to animals, and a salt accumulator which is grown in the same plot of land but separately harvested, may provide a valid solution. We report here preliminary results on the characterization of *Panicum turgidum* as a potential sustainable feed crop when grown in conjunction with *Suaeda fruticosa*.

2. Materials and methods

2.1. Identification of suitable species

Extensive surveys of the Sindh/Balochistan coast of Pakistan were conducted in which several herdsmen and herbalists of that

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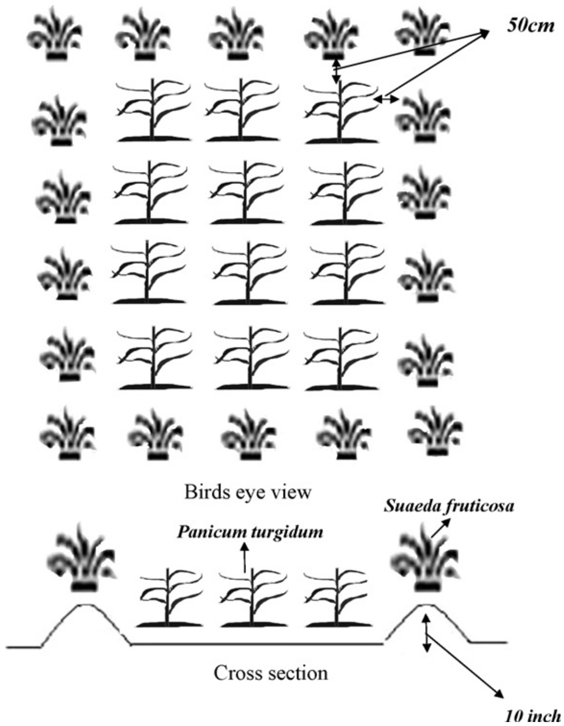

Fig. 1. Diagrammatic depiction of *Panicum turgidum* and *Suaeda fruticosa* (a salt accumulator) planting in the field.

area were included to acquire first-hand knowledge of existing halophyte species regarding their suitability and preference by local communities for use as forage/fodder. Plant characteristics including ease of propagation, availability of planting material, animal preference, biomass produced per unit time, perennial habit, and acceptability of local communities and growth performance were considered.

2.2. Plant growth

Several grasses (10 species) were identified and brought to the Zia Model Farm (owned by Zial-Haq & Sons. Inc.), Hub Kund, Balochistan, Pakistan (24°57′07.99″N, 66°45′23.74″E) for field testing and further scientific assessments. This farm has saline soil (EC 10-15 mS cm^{-1}) and uses brackish underground water (EC 10–12 mS cm^{-1}) for flood irrigation. Rhizomes of *P. turgidum*, which was selected as a suitable grass, were transplanted in plots of 5 m × 5 m size at 50 cm × 50 cm distance between rows and irrigated. Sprouting began after 10–15 days. Subsequent flood irrigation was applied fortnightly in quantities enough to keep the root zone moist during the intervening period but not enough to allow water to penetrate much deeper than the roots. For the purpose of diminishing soil salt content, *S. fruticosa* was used as a salt scavenger intercrop. *Suaeda* seedlings (10–12 cm high) were planted 50 cm apart on bunds between plots of *P. turgidum* and irrigated as needed (Fig. 1).

2.3. Chemical analysis

Dry matter and ash contents were determined by oven drying the samples until a constant weight was achieved. Plant samples were then converted to ash using a furnace at 550 °C for 8 h. Nitrogen was determined using a CNS analyzer and crude protein was calculated by multiplying total nitrogen content by a factor of 6.25 (AOAC, 2005). Total soluble protein concentration was determined using the Bradford (1976) method. Crude fiber and energy content were determined by the method described in AOAC (2005). Oxalates were determined using methods described by Karimi and Ungar (1986). Estimation of sugar was done following the methods of Ludwig and Goldberg (1956).

2.4. Animal feeding trial

Four groups of four calves each, balanced for age (1 year) and live weight (average about 140 kg) were used for conducting an animal feeding trial at the Farm using combinations of diet constituents, replacing freshly cut green maize with *P. turgidum* in variable quantities (Table 1). On August 21 and until slaughter the diet components were increased due to the larger size and feed intake of the animals. All animals were drenched against internal parasites and vaccinated for HS and FMD; individual animals showing symptoms of fever/cold/intestinal worms during the course of the experiment were treated accordingly. Fresh drinking water (EC 1.1 mS/cm, pH 7.5) was provided as needed and the animals were weighed periodically in the morning before feeding. They were slaughtered after 4 months and the meat yield and other characteristics were recorded.

3. Results

3.1. Characteristics of P. turgidum

P. turgidum Forssk. is a perennial grass of the family Poaceae distributed in salt-affected areas and deserts and is a salt excluder (Cope, 1982). As a grass, it has high potential for use as an animal feed. Establishing plants of this species through seeds is slow with poor germination, but it reproduces readily by transplanting root stocks. Plants attain a height of about 1 m in 25–30 days in summer (maximum temperatures generally between 30 and 35 °C). During the winter months of December to February (minimum 15–18 °C) it requires 35–40 days for comparable growth. The chemical composition of *Panicum*, analyzed as described (AOAC, 2005), is shown in Table 2. Several precautions were taken for the utilization of brackish water. First, irrigation was conducted more frequently

Table 1
Diet composition and quantities (kg/group of four calves) fed twice daily during the course of experiment.

Period of feeding	June 20, 2006–August 20, 2006				August 21, 2006–October 20, 2006*			
Feed constituents	Diet 1	Diet 2	Diet 3	Diet 4	Diet 1	Diet 2	Diet 3	Diet 4
Wheat straw	5	5	5	5	8	8	8	8
Maize	5	3	2	–	6	4	1	–
Panicum turgidum	–	–	1	3	–	–	3	4
Wheat bran	2	2	2	2	2	2	2	2
Concentrates	–	2	2	2	–	2	2	2
Total	12	12	12	12	16	16	16	16

* Diet composition was changed on August 21 due to the increasing size and corresponding feed intake of the animals.

Table 2
Comparative chemical composition (% dry weight) of *Panicum turgidum and Zea mays*.

Chemical	*Panicum turgidum* (%)	*Zea mays* (%)
1. Ash*	13	7
2. Crude fiber	18	25
3. Carbohydrates soluble at room temperature	25	?
4. Crude protein	13	11
5. Phenols	Trace	Trace
6. Oxalates		
1. Acid soluble	2.34	Trace
2. Water soluble	1.80	Trace
3. Total	4.14	Trace
7. Alkaloids	Trace	Trace

* Composition is mostly sodium and chloride.

but less intensely. The objective was to let the water leach through no more than 18 in. in depth and to keep the soil moist to prevent drying, which usually causes sodicity leading to insoluble salt complexes in the soil.

3.2. Use of S. fruticosa as a companion crop

S. fruticosa was grown as a companion crop with *P. turgidum* to remove the salt from the soil (Fig. 1). *S. fruticosa*, a member of the family Chenopodiacae and abundantly distributed in the area, is a salt accumulator with an ash percentage of dry matter of the leaf from 35% to 50% (Khan et al., 2000). Locals collect and burn leaves of this species to obtain soda ash which is then used to make soap. The level of salinity present both in irrigation water and the soil is much lower than the maximal concentration tolerated by this species, and hence it grows more rapidly than *Panicum*. The aerial part of the *Suaeda* plants (6 in. above the ground) must be cut frequently and independent of the fodder to prevent it from competing for light, water and nutrients with the main crop. This practice apparently functions to maintain salt balance and has allowed the system to be sustainable, as soil salinity has increased only slightly after a full year of irrigation with brackish water (Table 3).

3.3. Results of feeding trial

There was a progressive increase in the live weight of animals, carcass and weight of the body components (Table 4). The results for diets 2, 3, and 4 (Table 1) are similar and show little difference in growth between these diets, while all three were superior to the control (diet 1). This is expected due to the absence of a protein concentrate from diet 1. The concentrate is a costly item in the diet that is included for fattening. There is a need to use it judiciously, preferably during the last month of a fattening regime, although further experiments are needed for elaboration. Organoleptic testing revealed no difference in taste of meat due to the diet.

3.4. Advantages of P. turgidum as a fodder crop

In addition to high salts, some halophytic fodders contain undesirable organic compounds. *P. turgidum*, however, does not contain high salt, excess harmful organic constituents or secondary metabolites in the harvested foliage (Table 2). The ash is mostly composed of sodium and chloride, but the amount (13%) is not prohibitive for consumption, and may alleviate some of the need for salt licks typically provided to cattle in the area. For comparison, the ash content of several other local obligate halophytes ranges from 34% to 60% (Karimi and Ungar, 1986). Oxalates are present in much lower levels (4.14%) than in many other local halophytes (ranging from 14% to 29% in various species), and the water soluble form can be easily metabolized by the animals. There was no difference (data not shown) between the water requirement of the animals fed diet 2 (no *Panicum*) or diet 4 (100% *Panicum*). Animals under control (diet 1) remained smaller (Table 4) and more prone to disease compared to other diets (data not shown). Absence of a protein concentrate in this diet was perhaps the determining factor. Our data indicates that *P. turgidum*, despite being grown with brackish water irrigation, has similar effectiveness to conventional feed such as maize for animal production.

Table 3
Analysis of salinity levels of soil and irrigation water from test sites.

Sample #	Soil	Water*			
	EC (mS/cm)	EC (mS/cm)	Na (ppm)	K (ppm)	Ca (ppm)
April 07	7.0 ± 1.00	13.3 ± 0.31	4534 ± 380.00	44 ± 3.80	455 ± 4.00
June 07	8.9 ± 1.20	13.2 ± 0.22	4264 ± 300.00	40 ± 1.70	452 ± 2.10
August 07	9.0 ± 0.18	13.2 ± 0.23	4224 ± 445.00	39 ± 1.70	455 ± 4.80
October 07	8.7 ± 0.16	13.2 ± 0.35	4170 ± 335.00	52 ± 4.00	462 ± 1.00
December 07	8.5 ± 0.10	13.0 ± 0.31	3950 ± 170.00	41 ± 3.00	453 ± 4.00
February 08	8.0 ± 0.10	13.1 ± 0.41	3980 ± 400.00	41 ± 2.80	448 ± 3.20

* Irrigation water was from a 60 ft deep well adjacent to the plant growth plots, pumped to the surface for flood irrigation; pH of both soil and water remains 8.0 ± 0.2.

Table 4
Observations recorded at the termination of trial (mean of four replicates, ±standard error).

Observations	Diet 1 (control)	Diet 2	Diet 3	Diet 4
Live weight initial (kg)	136.0 ± 6.56	139.0 ± 5.06	139.1± 9.71	138.1± 7.45
Live weight at slaughter (kg)	167.0± 12.49	199.5± 2.06	192.3± 13.5	192.7± 11.93
Weight gain from initial (%)	23.0	43.3	37.2	38.4
Mean gain per week (kg)	1.9	3.8	3.3	3.4
Carcass weight (kg/animal)	75.2 ± 3.62	96.1± 3.49	93.6± 6.53	91.2± 4.91
Protein in meat (% dry weight)	65.4	64.4	72.9	70.3
Fat in meat (% dry weight)	25.2	28.2	25.1	24.9
Dressed meat (%)	45.9	49.7	49.0	47.6
Abdominal fat (kg/animal)	1.4± 0.06	1.6± 0.15	1.5± 0.1	1.0± 0.05

3.5. Panicum as a component of cattle feed

Cattle generally will not eat low quality fodder if more palatable feed is available, and this is perhaps the reason behind the exclusive use of goats and sheep (considered more salt tolerant) as test animals in most halophyte feeding trials (Master et al., 2006; Morecombe et al., 1996). Furthermore, many of these trials involved grazing in a field where the animals have the choice of selecting one component of the vegetation or rejecting others at will. There is little published work on controlled feeding of halophytes to cattle, and to the best of our knowledge the present study is significantly different from the efforts so far in this context because *P. turgidum* was harvested and fed to the animals on a scheduled and controlled basis. Conservative estimates based on these results suggest that the use of *Panicum* as a major component of cattle feed may be expected to generate a profit, especially when expanded to feed more animals (data not shown). There is also a greater potential economic impact due to the utilization of poor quality water and saline land resources which are generally considered as waste and otherwise would not be utilized.

4. Discussion

4.1. Panicum as a major component of cattle feed

The results from this ongoing study indicate that substituting *Panicum* for the maize component completely in the diet results in equivalent cattle growth and meat production, without the need of low salinity soil for maize production, freeing up non-saline soils for other essential crops. There was no difference in yield or taste of meat from the animals fed each diet and the venture has the potential to be economically viable. We are in the process of finding suitable replacements of other components of the diet and a source for protein concentrate which could be produced using the same saline resources.

4.2. Estimates of yield

Based on the above experimental conditions, plant survival of 60% and per plant yield of 200 g, *P. turgidum* is expected to produce about 5000 kg green fodder per month (more or less 60 ton/year)/ha. With optimized cultural practices (proper irrigation, added fertilizer/farmyard manure, closer spacing etc.), an increase in yield cannot be ruled out, as reported by Edwards et al. (2004). Our preliminary trials show promising results with NPK fertilizers applied alone or in conjunction with organic manures (data not shown).

4.3. Benefits of Panicum as a feed crop in areas with saline soils

We believe that the combined growth of *P. turgidum* and *S. fruticosa* as an intercrop, along with frequent irrigation with brackish water, addresses several important limiting factors:

1. Use of *S. fruticosa*, a salt accumulator, in combination with *P. turgidum* has proven to be effective. Soil salinity has registered only a marginal increase during a full year of irrigation with brackish water (Table 3). Growth of *Panicum* alone leads to rapid salinization of the soil (data not shown).
2. *P. turgidum* is a perennial and can be continually harvested to about 60,000 kg/ha/year without reseeding, saving considerable time and resources. Our agronomic work in progress also indicates increased production with proper fertilizers including organic manures.
3. Eating high salt diet accentuates animal thirst but chemical analysis of the leaf tissue of *Panicum* indicates low (13%) ash content, which is much lower than that for salt accumulators (34–60%) (http://beefmagazine.com/nutrition/feed-composition-tables/beef_feed_composition/).
4. Harmful secondary metabolites such as alkaloids and oxalates (4% in *Panicum* compared to 14–29% in other halophytes) are present in much lower amounts in foliage compared to many halophytes and therefore are little threat to feeding animals.
5. Animals readily eat *P. turgidum* as a main feed component in place of maize, without any significant effect on animal thirst or growth and meat production.
6. It is often difficult to convince farmers to change their preferences for growing feed. In this case care has been taken to involve local farmers in the decision making process and therefore they have readily accepted *Panicum* as a fodder crop, which had not been previously cultivated. Current trials with goats and sheep indicate a similar pattern of successful utilization of this grass in the feed.

5. Conclusion

In our preliminary work reported here *P. turgidum* appears to be a high-quality fodder grass for the coastal area of Pakistan, and should be suitable for other sub-tropical regions of the world. It can grow from coastal dunes to inland regions. Its salt tolerance may vary from one location to another due to variability in local populations. We recommend initial experimental production of this grass in new areas before full scale cultivation is initiated. We believe that we have a mechanism for growing a halophyte grass for feed that, if properly implemented, could contribute significantly in utilizing currently unused saline land and providing fodder to arid areas that have abundant saline water resources. The communities along the Balochistan coast, for example, are extremely poor and the introduction of this grass in that area would provide an economic benefit. This may not only help Pakistan and other developing nations with large areas of saline land to meet their meat and dairy production requirement but also earn badly needed foreign exchange.

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