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‘*Prosopis* for prosperity’: using an invasive non-native shrub to benefit rural livelihoods in India

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Prosopis juliflora **is an invasive non-native shrub species which has an adverse impact on natural habitats in many parts of India, with detrimental effects on both wildlife and traditional livestock-based economies. Attempts to eradicate this very adaptable and resilient species tend to be unsuccessful and expensive. Here we report on two management techniques that could be used not only to minimize its ecological impact, but also to acknowledge its value as a resource to support rural livelihoods: biochar production and the creation of stock-proof living fences.**

Keywords: Biochar, living fence, *Prosopis juliflora*, rural livelihoods.

THIS study was undertaken in response to the need for soil improvement and stock-proof fencing that emerged during a participatory ecosystem services assessment of the coastal plain of Kachchh district, Gujarat, India[1,2]. The project, funded by the British Council UK–India Education and Research Initiative (UKIERI), was initiated due to concern about the spread of *Prosopis juliflora* and its impact on native plant species, particularly in the grasslands which are highly valued for wildlife and are a traditional grazing resource[3]. *P. juliflora* is native to South America and was introduced to Kachchh in the 1960s to prevent the Rann desert from encroaching onto the Banni grassland, an important area for grazing and biodiversity. Remote sensing data show that the shrub has spread at a rate of about 25 km^2/yr, and it is predicted that by 2020 more than 56% of the grassland will be under *P. juliflora*[4]. The species has colonized the arid Kachchh landscape so successfully that ecologists are now recommending that steps should be taken to eradicate it. In some areas it has replaced native species such as *Prosopis cineraria* and gugal (*Commiphora wightii*), which are important sources of medicine for local people[5]. The invasion of pastureland by *P. juliflora* threatens traditional livestock-based economies: the thorny shrubs restrict access to water, and can cause injury to the animals. While the pods can be used as a high protein feed for goats, sheep and camels, the high sugar content makes them indigestible for buffalo and cattle[6].

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Direct observation showed that clearance of the shrub from agricultural plots can be successful, and that the areas where the shrub proliferates are the common grazing grounds which are considered to be important for native wildlife[7]. However, eradication of this plant is not a realistic option as it is very adaptable, able to withstand drought and high levels of soil salinity, and has an extensive root system[8]. Experiences from America, Asia and Australia have all shown that attempts to eradicate *P. juliflora* using different methods are highly expensive and largely ineffective, and that management strategies should be used instead that minimize its ecological impact and acknowledge its value as a resource to support rural livelihoods[9]. Indeed, *P. juliflora* has become an important part of the local economy in Kachchh, with different parts of the plant providing timber, fodder, gum, honey, a cotton-like substance, and wood for fuel and charcoal production[3,10]. Charcoal production is a significant livelihood in some villages, and is practised particularly by the Koli tribe[11]. Charcoal made from *P. juliflora* has a higher calorific content than that made from native species[12], and so is considered to be of higher quality.

Focus group discussions held in eight villages of the Kachchh coastal plain confirmed both an increase in the extent of *P. juliflora* and its importance as a source of fuel. Other issues raised by the villagers included increased soil salinity, which reduces crop yields and the quality of grazing land, and predation of crops by wandering domestic livestock and wild animals[1,2]. An extension was granted by the British Council to enable the present authors to return to Gujarat to investigate whether *P. juliflora* might in fact offer a solution to these problems, by providing a source of biochar which reduces soil salinity, and for making stock-proof living fences. Biochar production and hedge laying were demonstrated at a workshop held at the Vivekanand Research and Training Institute (VRTI), Mandvi, in June 2016, which was attended by farmers, landowners, local authority and Forest Department representatives, as well as rural development professionals. Illustrated information sheets were distributed in both English and Gujarati; electronic copies have subsequently been requested and e-mailed to those wanting to distribute them in other parts of Kachchh and beyond.

Like charcoal, biochar is made from biomass, usually wood, through pyrolysis. However, while charcoal is produced to make fuel, biochar is produced to make a soil amendment. When used alongside appropriate sources of nutrients like green manure, animal manure, or compost, it has been demonstrated to improve soil quality and crop growth. In addition to reducing soil salinity, biochar provides appropriate conditions for beneficial soil microbes such as nitrogen-fixing rhizobia and mycorrhizal fungi, and improves the physical properties of the soil. Being highly porous, it retains water, potentially making it available to plants in times of drought. Biochar can also improve water infiltration at the soil surface, and reduce soil compaction. The high pH of biochar is beneficial in soils where the pH is lower than optimal for the intended use, and ash contributes some nutrients to the soil, such as calcium, potassium and magnesium, and micronutrients, including zinc and manganese, though this is a short-term effect. However, over time biochar surfaces develop an ability to retain nutrients in the soil. Therefore biochar has the potential to provide benefits for soil quality both in the short- and long-term. The long-term benefits of biochar are unique to this soil amendment, since other organic amendments decompose rapidly in the years after they are applied. However, biochar is variable in quality, depending on the type of biomass used, the pyrolysis conditions (temperature, time for which biomass is held at a given temperature, and heating rate during pyrolysis), and whether it is enriched with other compounds[13]. The effectiveness of *P. juliflora* to produce biochar which increases soil fertility and consequently crop yield, has already been established[14–18]. One of the major characteristics of *P. juliflora* biochar that makes it attractive as a soil amendment is its highly porous structure, which results in improved water retention and increased soil surface area.

The traditional way of making charcoal in Kachchh is the earthburn, an effective technique but one that involves constant surveillance as the yield will be significantly reduced if the seal is broken and air enters the chamber. More efficient techniques have been developed elsewhere, such as using a ring kiln, which requires investment in a large metal container and collecting a large volume of wood for each burn, and permanent built structures[18]. The most efficient method, in terms of both conversion rate and time, is the retort, where the heat source is kept separate from the material to be converted into charcoal/biochar. However, commercially available retorts, such as the Exeter Retort[19], are costly and beyond the means of most full-time charcoal producers in the UK. The aim here was to demonstrate a cheap method for local farmers to produce small quantities of biochar for their own use as a soil improver with the additional benefit of the removal of *P. juliflora* from their fields.

A series of experiments was undertaken to check whether readily available metal drums that had been previously used for oil or chemicals could be used to make a retort. The drums were selected by size so that the smaller drum would fit into the larger one, leaving a space of about 20 cm all around. A chimney was made by cutting a hole in the lid of the larger drum and welding a pipe into it (Figure 1). The smaller drum, the inner chamber, was then packed tightly with small pieces of *P. juliflora* wood and inverted into the larger outer drum. The space between the drums was filled with dried palm leaves, coconut fibre and other flammable material; this also filled the space between the base of the inner chamber and the lid. This material was lit and, when burning steadily, the lid was placed on top and weighed down with stones. For the second experiment, an air hole was made at the bottom of the outer drum and the retort was placed so that the air hole faced the direction of the wind, thereby providing an air intake (Figure 1). For each experiment the retort was left overnight and the lid was only removed when the retort had cooled completely. This enabled the retort to be laid horizontally and the inner drum to be removed. Three burns were completed; Table 1 shows the differences between them. Table 2 provides results from the three experimental burns. Full success was achieved in the final experiment (Figure 2). If a second smaller drum for the inner chamber had not been available, similar success would have resulted if the space between the drums in burn 2 had been repacked and the burn repeated. The retort method therefore proved to be a cheap and easy way of making biochar from *P. juliflora*.

The second experimental demonstration involved making a stock-proof living fence with *P. juliflora* shrubs using the hedge-laying technique, which is widely practised in England. When a line of plants, referred to as a 'hedge', has grown taller than about 2 m, the stem of each individual plant is partially severed as close to the ground as possible, ensuring that the cambium and some of the sapwood remain intact so that the attachment of the stem to the stump is secure. The stems are then bent down to an angle of 45° or less to the ground. Hedge-laying is done during the winter, when the plants are dormant, and stakes are inserted at regular intervals to hold the stems in place, with further flexible plant material (referred to as rods) used to hold the top of the stakes together and present a neat finish. During spring, the

Table 1. Differences among the three experimental burns

Burn number	Description
B1	Smaller drum filled with *Prosopis juliflora* inverted into a larger drum. Space packed with flammable material which was burnt.
B2	As in B1, but with additional air inlet to provide updraft.
B3	As in B2, but using a smaller drum for the inner chamber and a greater quantity of flammable packing between the drums.

Figure 1. The chimney welded onto the lid of the outer drum.

Table 2. Results from the three burns

Burn number	Description
B1	On opening the inner chamber, the *P. juliflora* material was found to be partially charred. This suggested that either the temperature reached was not high enough, or that it did not last long enough to complete the charring process.
B2	The addition of an air inlet in the base of the outer drum was intended to increase air flow and also the intensity of heat. This was found to increase the proportion of black (fully charred) to brown material in the inner drum.
B3	A smaller inner drum was used. The air inlet combined with more flammable packing resulted in a longer burn and the contents of the inner chamber were found to be fully charred.

Figure 2. Full charring after the third experiment.

Figure 3. A cut at the base of the stem of *P. juliflora*.

Figure 4. A demonstration living fence at Vivekanand Research and Training Institute, Mandvi.

Figure 5. The living fence showing growth after four months.

stems and stumps will sprout and will produce a dense and bushy hedgerow within two years. In England, hedge-laying is a routine management operation undertaken to maintain hedges in a stock-proof condition. It also plays a key role in ensuring the long-term survival of hedgerows, as periodic laying can greatly increase the natural lifespan of hedge plants, since the process stimulates the growth of new shoots.

The first experiments using *P. juliflora* were performed in May 2016, when a heat wave was affecting northwestern India. Appropriate cuts were made using tools brought from England on plants growing on waste ground just outside the compound of the Gujarat Institute of Desert Ecology, Bhuj (Figure 3). The response of the plants was closely monitored to assess wilting and recovery. Only one stem wilted and, on subsequent examination, this proved to be due to accidental twisting which had occurred while it was being lowered towards the horizontal position. The next step was to repeat the initial experiments using locally purchased tools. These were then used to prepare a demonstration living fence at VRTI (Figure 4). The living fence has subsequently been monitored and is growing well, with vertical shoots growing from the near horizontal stems (Figure 5).

These experiments clearly demonstrate that *P. juliflora* can be used to make stock-proof living fences and biochar. This provides a potential solution to the problem of wild and roaming domestic animals predating agricultural crops, as well as a cost-effective means of improving the water and nutrient-holding capacity of the soil. The importance of this knowledge transfer exercise is twofold. First, low-/no-cost solutions have been applied to real problems that impact rural livelihoods. Secondly, using *P. juliflora* for these purposes will have the added benefit of reducing its prevalence and further spread. It is suggested that setting up a commercial biochar (or charcoal) production facility near to important grasslands could provide an incentive for small-scale eradication of *P. juliflora*, which would benefit wildlife and also provide additional local employment opportunities.

P. juliflora is widespread across India and the techniques described here – using it to produce biochar and construct stock-proof living fences using locally available tools – could have much wider applications. The very characteristics that make *P. juliflora* a 'problem', i.e. its ability to spread rapidly and extensively, even in hostile environments – can be utilized for the benefit of rural livelihoods.

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Effect of primary tillage implements on physical properties of harvested Spunta potato tubers

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We study the effect of implements on the physical properties of the produced potato tubers. These potatoes were classified as grade A. There was a significant difference in tuber shape index among the tillage implements. The results showed that the tuber weight of fresh potatoes was 179.28–201.64 g, and the bulk density was 1.066–1.068 g/cm^3. There were no significant differences among the physical properties. Thus, it is appropriate for a farm to select any of the studied tillage implements that are available.

Keywords: Physical properties, potatoes, tillage.

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IN many countries, potatoes are essential crops because they are a complete and inexpensive food[1,2]. Customers pay considerable attention to the appearance of potatoes. Soil tillage is required prior to potato seeding, because tuber crops require loose and deep soil that is permeable to air and water[3]. Thus, soil tillage is considered the most important operation affecting the shape and physical properties of a potato[4].

Mechanization consists of land preparation, planting, cultivation, harvesting and post-harvesting practices, all of which affect potato production[5]. Every mechanization process (soil tillage, for instance) affects the quantity and quality of produced potatoes[6]. However, soil tillage is a significant operation, because it provides a suitable environment for potato roots to enter the soil and maintains an adequate amount of water for plant consumption. Tillage implements directly affect planting depth, which is the primary factor influencing the yield and tuber quality of potatoes[7]. Also, tillage implements should loosen the soil as much as possible to support the ability of planter openers to easily reach the chosen planting depth[4]. A 10–15 cm planting depth is recommended for potatoes for most soil types in Saudi Arabia[8]. The tillage depth for potato production can be 15–18 cm when using minimum tillage, 22–25 cm when using conventional tillage and 33–35 cm when using deep tillage[9]. For soil tillage preceding potato seeding, reduced tillage at an 8 cm depth could achieved by a disk harrow, medium tillage at a 20 cm depth by a disk plow and a 30 cm depth by a moldboard plow[10].

The shape of potato tubers is one of the most important factors in classification and grading related to commercial quality and organoleptic properties[11]. The shape of Alpha potatoes is oval and that of Spunta potatoes is elongated[12]. Also, the average bulk densities of fresh Dimont and Santana tubers are 0.968–1.26 g/cm^3 and 0.924–1.221 g/cm^3 respectively[13]. Additionally, inter-row subsoiling does not significantly change the specific gravity of tubers[14].

Field preparation for potato planting is important, and using a suitable tillage implement can play a key role. However, the physical properties of agricultural products are the most important parameters in the design of grading, handling, processing and packaging systems. Among these physical properties, weight and volume are most important in handling systems[15]. Other important parameters are width, length and thickness. Knowledge of