outdoor ambient summer (day) temperature ranging between 40 and 45°C while the VAM-inoculated plants successfully survived such harsh conditions (Table 1). VAM colonization of plant roots *in vitro*, raises the possibility of producing effective propagules (vesicles/spores/mycelium) which could be recycled and used for inoculating micropropagated plants while maintaining aseptic conditions.

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ACKNOWLEDGEMENTS. We thank Mr Desh Raj for graphics, Prof. Jim Trappe and Dr Deepak Pental for their critical and helpful discussions. Support for this study by the Director, Tata Energy Research Institute, New Delhi and International Development Research Centre, Canada, is gratefully acknowledged.

14 September 1989; revised 5 September 1990

# Ethephon-induced gum production in *Acacia senegal* and its potential value in the semi-arid regions of India

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**Gum arabic has multifarious applications and is imported to India annually in large amounts. For some unknown reasons the source tree, *Acacia senegal*, which occurs abundantly in our country, does not yield gum. A preliminary study revealed that 0.8 to 0.9 kg of good quality gum can be obtained per tree, by introducing 4 ml of ethephon solution containing 960 mg of the active substance through a hole in the sapwood in April/May. A detailed study could extend the value of this finding to utilize a source presently untapped, generate revenue from unproductive semi-arid lands and substitute imports.**

ACACIA SENEGAL Willd. is a tree with multiple uses that occurs naturally in the barren, arid and semi-arid tracts of India. When the tree's main stem or its gnarled spiny branches are wounded, the tissues beneath the bark produce a viscous exudate that dries up to walnut-sized spherical mass. This constitutes gum arabic, an important trade item since biblical times[1]. The Egyptians used it in ceramic pottery and medicines over 4000 years ago[2].

Gum arabic is highly soluble in water and is a good emulsifier, with low viscosity. The gum is odourless, flavourless, safe and finds widespread use in important industries such as paper, textile, adhesives, minerals, fertilizers, explosives, pharmaceutical, cosmetic, soap, ceramics, food, beverage and confectionary[1–4]. Throughout the Old World, gum arabic has been used in foodstuffs and beverages since antiquity. In 1961, gum arabic was classified by the US Food and Drug Administration as being 'generally recognized as safe', as a food stabilizer and affirmed its direct use in foodstuffs[2]. When present in the diet, at levels less than 10%, gum arabic is completely digested and absorbed[5]. Comprehensive dietary and toxicological tests carried out on gum arabic in humans have led to its acceptance as a component of foodstuffs and medicines[6].

Extensive stands of *A. senegal* trees, both wild and planted, occur in the arid and semi-arid regions of Kutch (Gujarat) and Rajasthan. Strangely, the trees exude little or no gum. Natural wounds (e.g. breaking of branches by wind, injuries by birds, etc.) also cause little or no exudation. India is consequently importing annually around 5000 tonnes of gum arabic worth 7.3 million rupees from Sudan which provides 75–85% of the world's supply[7]. With the rising consumption of gum arabic in India, there is a definite need for tapping indigenous plants. Economical methods of tapping must be evolved and standardized to achieve optimum annual production of gum arabic on a sustained basis and also to ensure the survival of the trees in the wild.

Ethephon (2-chloroethylphosphonic acid, a synthetic chemical compound which releases ethylene in plant tissues) has been used for enhancing latex flow in para rubber (*Hevea brasiliensis*)[8,9] and resinosis, gummosis and gum-resinosis in several plants[10–13].

In the present study, we have extended its use for inducing gummosis in *A. senegal* trees. We have worked out the optimum concentration of ethephon for maximum yield of the exudate without visible adverse effects on the plants. Ghosh and Purkayastha[14] have made a detailed study of the anatomy of bark/wood tissues responsible for gum formation. Therefore, this aspect is not dealt with in the present paper.

Twelve *A. senegal* trees of comparable size and vigour growing in Chambal ravines near Barhi, Madhya Pradesh were selected for experimentation during April/May, 1988. Nine plants were treated with ethephon and three plants were kept as controls (distilled water-treated). A commercial preparation of ethephon (purchased from Agromore Ltd, Mysore Road, Bangalore, India) containing 480 g/l of ethephon in various dilutions used in this study is referred to as active substance in the text. Aqueous solution of ethephon was used in dilutions containing 480, 720 and 960 mg of the active substance per 4 ml respectively. A preliminary trial was also made in which different concentrations of the active substance were used on seven plants (growing at Sindh river ravines, Dabra, Madhya Pradesh) at random and the most appropriate range was determined. As concentrations above 960 mg induced 'shoot desiccation' and 'die back' they were not used[15].

Holes measuring 5 cm deep × 2.5 cm wide were made in the main trunk at about 1.0–1.5 m above the ground level using a chisel and hammer. The opening slanted downwards and reached up to the outer sapwood. Four ml of ethephon solution was introduced into each hole and it was covered with bee wax. An area measuring 2.5–4.0 $cm^2$ of the bark, above the treated holes, was deliberately bruised to encourage increased gum production. The experiment was run in triplicate. The results are presented in Table 1.

A stand of five trees being maintained in the Beriganga plot of the Central Arid Zone Research Institute (CAZRI), Jodhpur were also used to verify our findings. The results are given in Table 2.

A hole (arrow) made on the control tree is shown in Figure 1. The treated plants started exuding gum through the holes after 4–8 days. Exudation first started in the plants treated with the highest concentration (960 mg) of the active substance. A portion of the tree trunk treated with 960 mg of active substance and showing gum flow is depicted in Figures 2 and 3. Uninjured trees failed to exude gum. Control plants produced only 2 g of gum (Table 1). Over 100 times increase in gum production over the control was noted in response to 480 mg of ethephon. The yield was enhanced by increasing the amount of ethephon. The highest amount of gum was produced when 960 mg of the active substance was applied. Kaul and Jain[16] had reported that blazing with axe and followed by application of sulphuric acid stimulated individual trees to give an annual average yield of over 40 g during the ideal tapping season (May–June).

Table 1. Yield of gum from treated plants at different concentrations of ethephon during April/May in Chambal ravines near Barhi, Madhya Pradesh, (data pooled from three replicates).

| Active substance of ethephon (mg/4 ml) | Mean amount of gum (g)* |
|---|---|
| 0 (control) | 2 |
| 480 | 210 |
| 720 | 305 |
| 960 | 950 |

Untreated plants produced no gum.
*Decimal figures are not included.

Table 2. Yield of gum from five plants (growing at Beriganga CAZRI plot, Jodhpur), each treated with a different concentrations of ethephon.

| Active substance of ethephon (mg/4 ml) | Amount of gum (g)* |
|---|---|
| Control | Nil |
| 240 | 121 |
| 480 | 183 |
| 720 | 289 |
| 960 | 806 |

*Decimal figures are not included.

The exuded gum presents a variety of forms—globular, tear-shaped, or irregular masses (Figures 3–5). The surface of the freshly exuded gum is smooth. In course of time, it becomes rough or covered with minute striations (Figure 6) due to weathering.

In the CAZRI plot at Beriganga the control trees did not exude even a drop of gum (Table 2). However, of the five plants treated with ethephon, the one that received 960 mg of the active substance exuded 806 g of gum (Table 2).

Over 100 species of *Acacia* are known to exude gum when their bark is stripped. These plants grow in extremely arid and inhospitable areas where conventional agriculture is not feasible and poverty is rife. In the Sahelian region, there are nomads whose annual income of around £ 50 is derived entirely from the sale of gum collected from *Acacia* shrubs — mainly *A. senegal*[17]. Not so long ago, the sale of gum collected by the tribals in north Africa constituted their major single source of livelihood. Gum trees were their treasured possessions and fights to death to retain ownership were not infrequent[6].

Although the amount of gum produced varies from year to year and its price fluctuates considerably with market conditions, the production of gum arabic in recent years is estimated to be around 50,000 tonnes, valued at £ 35 million. The current price ex Port Sudan is US $ 1500 per tonne[6,17]. Several Asian countries are interested to enter the gum trade.

We believe that if a simple, inexpensive method of tapping is practised and organized collection of gum arabic are followed, India should not only be able to


**Figures 1–6. 1,** Control wound (arrow) on the main bole. **2,** Treated site on the trunk showing profuse gum exudation (arrow) from the hole. **3,** Tears of gum (arrows) exuding from the stem surface. **4,** A portion of main bole showing gum exudation (arrows) above the tapping cut. **5,** A close-up of gum ball hanging on the stem surface. **6,** A sample of gum arabic obtained in the present study.

meet its requirement and save foreign exchange but could also enter the international market. The samples of gum arabic collected during the present work and shown to the traders in Delhi appear to make the international grade. There is scope for about 20,000 tonnes of Indian gum arabic consumption in the markets of America and Europe[18].

It is suggested that in the afforestation programmes for arid and semi-arid zones of India, *A. senegal* should be considered as a potential planting material. *A. senegal* is the only *Acacia* involved in afforestation of the recognized Sahelian gum belt. For many years, the Sudan gum traders even followed a policy of regenerating only *A. senegal* and eradicating other *Acacia* species[2].

Gum arabic is a complex substance, with many unique features and properties. It is unlikely to be duplicated or reproduced by any viable man-made synthetics or modified natural substitutes. For many applications, the performance of gum arabic in a wide range of products is considered superior to other available substitutes[2, 6].

In Sudan, gum arabic is the third most important export item after livestock and cotton[19]. But *A. senegal* is more than an export earner. It is a vital source of income and employment to farmers who can tap the trees in the dry season when there are no other crops to tend. The deep tap root extends down the water table and the extensive lateral roots that reach ~ 100 m in length take the advantage of light showers, stabilize the soil and limit the risk of desertification. The tree also fixes nitrogen and encourages the growth of grasses around the trunk. The tree is a source of fodder and fuel. The naturally shed leaves and pods decompose and add nitrogen-rich organic matter to the soil[7]. Yields of crops increase when farmers intercrop or rotate *A. senegal* with other crops. Therefore, *A. senegal* has an economic value, significantly beyond that of the gum it produces. Raising *A. senegal* either in plantations for agroforestry or in small plots for social forestry can result in high rates of return, especially when the environmental benefits are added to the value of the gum.

The utilization of the initial finding reported here will require scaling-up of sample size, collection of data over longer periods, examination of wound-healing responses and estimation of yields of trees from different provenances.

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ACKNOWLEDGEMENTS. We are grateful to Dr Ram Prasad, Director, State Forest Research Institute, Jabalpur; and Dr J. Venkateshwarlu, Director, Central Arid Zone Research Institute, Jodhpur, for providing facilities to work on *Acacia senegal* trees growing in Chambal ravines and in Jodhpur respectively. J. R. B. thanks the Department of Science and Technology, New Delhi, for financial assistance.

12 July 1990

## α-Hexachlorocyclohexane: a potent insect growth regulator

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**The inactive α-isomer of hexachlorocyclohexane (α-HCH or BHC) caused morphogenetic effects in fifth-instar hoppers of *Schistocerca gregaria* (Forsk.) when injected into haemolymph or administered through food. A dose as low as 2 μg α-HCH, when injected into 3-day-old fifth-instar hoppers, caused defective metamorphosis in 50% of the treated population. The fourth-instar hoppers moulted directly into adults when α-HCH was either injected or administered topically or through food. Administration of cholesterol along with α-HCH resulted in dose-dependent reduction in the deformities caused by α-HCH.**

AMONG synthetic insecticides, hexachlorocyclohexane (HCH or BHC) is the oldest of the organochlorine insecticides. It comprises α, β, γ, δ and ε isomers; only the γ is responsible for insecticidal properties. The other, inactive, isomers are by-products in the pesticide industry and cause disposal problems. While they are