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Biomass and Biodiesel for Energy Production from Salt-Affected Lands

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INTRODUCTION

Government of India has chosen bio-diesel produced from oil-bearing seeds of Jatropha *(Jatropha curcas)* and Pongamia *(Pongamia pinnata)* as a substitute for HSD (high-speed diesel) under the National Mission on Bio-diesel (NMB). The challenge is to produce large quantities of biofuels at prices competitive with those of currently used fossil fuel products on a sustainable and environmental friendly basis with particular emphasis on the under-utilized and less productive lands. Initial efforts in this direction, produced mixed results due to lack of information, systematic research and lack of knowledge about suitable and productive lines and silviculture practices in different soils and agro-climatic situations. In the present scenario, when most of the cultivable area has been occupied by conventional / cultivated crops, plant species having tolerance to different stresses and having potential to produce reasonable biomass in degraded land under less favourable environmental conditions need to be promoted.

In view of the emerging national priorities for achieving energy security and making judicious use of salt-affected soils several studies have been initiated at CSSRI, Karnal and its Regional Research Centers located in different agro-climatic conditions of the country. The ultimate goal is to develop site-specific suitable genotypes that are tolerant to adverse growing conditions such as salinity, alkalinity, waterlogging and frost, so as to promote their cultivation in such areas.

Jatropha curcas (L), known as Ratan Jyot or Vana Erand, is fast growing, providing a source of renewable energy, produces useful oil from its seed and is also a good soil conservation plant, adaptable as a wind break and has other multiple uses. Jatropha, which already grows in several parts of India, is domesticated all over India for more than 400 years, is moderately resistant to drought, and thrives in arid and semi-arid areas. It is a vigorous plant and is not eaten by animals. It provides environmental benefits such as protection of crops or pasture lands, as a hedge for erosion control, or as a windbreak and a source of organic manure and fuel wood. Similarly, another multi-purpose tree species *Pongamia pinnata*, known as karanj or papri is also being propagated in the NMB.

POTENTIAL & SCOPE OF BIOFUELS

India is reported to have 107 million hectares of wasteland and it may be possible to bring 10 to 20 per cent of this land under cultivation of plants that can yield biomass for energy. As per estimates of the International Energy Agency, farmers could supply the world with about 10 percent of its gasoline by 2025. Biofuels can be produced from a wide range of feedstocks, from traditional corn or rapeseed oil, or the more unconventional used cooking oil or cheese. Edible oils are used as biodiesel in Europe, USA and other countries, whereas for countries like India which are already short of edible oils, use of non-edible oils only seems to be a suitable option. In countries like Brazil, USA and Canada where food gains like corn and wheat are being diverted for ethanol production, India cannot afford this option owing to limited area for food production to feed a population of about 1.1 billion.

Jatropha is a multipurpose plant whose every part has some economical value. Plants start producing oil-bearing seeds within one or two years of planting and optimum yields are obtained by three to five years and plants are reported to be productive up to 45- 50 years. The main economic part of Jatropha is its kernel. The oil content is reported to vary from 25-35 per cent in the seeds and 50-60 per cent in the kernel. The oil contains 21 per cent saturated fatty acids and 79 per cent unsaturated fatty acids. Jatropha oil is also used as an illuminant as it burns without emitting smoke. Its latex contains an alkaloid known as “Jatrophine" which is reported to have anti-cancerous properties. It is also used as an external application for skin diseases and rheumatism and for sores on domestic livestock. Roots are reported to be used as an antidote for snake-bites. We have tried to gather information about the various uses of different parts of Jatropha and Pongamia and these are summarized in Table 1. Proper awareness about various uses and products from different parts of Jatropha along with suitable value addition will boost its economic competitiveness and real contribution to rural development programmes.

Potential Areas for Cultivation

As per estimates of the Ministry of Rural Development (MoRD), the following areas have potential for cultivation of Jatropha

- About 3.0 million hectare (notional) of land in the under stocked forests out of the total forest cover
- Two m ha of notional plantation is expected on land held by absentee landlords
- On wastelands under Integrated Watershed Development and other poverty alleviation programmes of Ministry of Rural Development a potential of 2 m ha of plantation is assessed

Table 1. Uses of *Jatropha* and *Pongamia* multi purpose tree species

Part	Jatropha	Pongamia
Seeds	Biodiesel, Glycerine	Biodiesel
Oil cake	Bio Manure	Bio Manure, Poultry feed & Insecticide
Stem & Cuttings	Toothache, Gum bleeding & Pyorrhea, Wood and cuttings for fuel available every year after pruning, Dye for colouring cloth and fish nets Good potential to produce Biomass	Fuel, Timber for furniture & different Implements
Leaves	Aqueous Extract Insecticidal properties, Fumigation of houses, As Tussar Silkworm feed, Dye for colouring cloth and fish nets Leaf litter is a good source of organic matter and nutrients	Insecticidal properties, Fodder
Leaves, Latex & Roots	Medicinal uses (Laxative, Arthritis, Gout & Jaundice, Antidote for Snake bite, Anti-Cancer drugs , Anthelmic	Medicinal use in Gout & Skin diseases
Plants	Hedge, Tree & Plantation Crop	As Shade & Ornamental Tree on roadside
Production Starts	1-3 Years	Starts after 5 Years
Age	Up to 40-50 Years	> 50 Years
Origin & Popularity	Origin from Mexico & S. America	Origin in South Asia

- One m ha of notional coverage with Jatropha on vast stretches of public lands along railway tracks, roads and canals.
- Jatropha hedges around agricultural fields can amount to 3.0 m ha (notional) plantation.

OBJECTIVES

Studies on Jatropha and Pongamia are being conducted by a multi- disciplinary team of scientists at Central Soil Salinity Research Institute, Karnal and its three regional centers with the following objectives:

Short -term

- To acquire, evaluate and identify plant species and varieties from different areas / sources to increase genetic diversity suitable for alkali, saline soils and saline-vertisols
- To develop a germplasm base to promote their economic production in saline agriculture (saline / sodic soils and waters)
- Screen species for germination, propagation, seedling, vegetative and reproductive growth under salinity / sodicity in pots, micro plots and field situations to assess their productivity

Long-term

- Physiological mechanisms governing tolerance/ susceptibility of lines/ clones of Jatropha and Pongamia
- Monitoring of the target sites for soil-plant interactions with focus on accumulation and toxicity of salts and microelements in plant parts and rhizosphere
- Studies on water and nutrient uptake patterns, availability and utilization, processes of gas exchange, photosynthesis and C-sequestration
- To develop a package of practices for raising Jatropha and Pongamia plantations in salt affected soils
- Establishing germplasm orchard of tolerant and productive lines of these species

Ultimate objective is to identify suitable and productive genotypes / varieties tolerant to adverse growing conditions such as salinity, alkalinity, water-logging and frost so as to increase the range of growth / cultivation.

In order to achieve the above objectives and to exploit and promote the potential of Jatropha and Pongamia for energy generation and identify the tolerance potential for saline, alkali / sodic soils and irrigation with poor quality waters besides suitable agricultural practices for optimum productivity, a series of experiments were initiated at CSSRI Karnal and its Regional Research Stations at Lucknow (UP), Bharuch (Gujarat) and Canning Town (West Bengal), the following experiments and studies were initiated:

- Evaluation of plant tolerance to salinity and alkalinity/ sodicity stresses in pots and fields
- Studies on irrigation, fertilizer, spacing, pruning requirements and intercropping in semi-reclaimed alkali soil at Karnal
- Performance evaluation in highly alkali soils at Lucknow, Uttar Pradesh
- Performance evaluation in saline vertisols in Bharuch, Gujarat
- Performance evaluation in coastal saline soils in West Bengal

SALIENT RESEARCH FINDINGS

In this brochure, some of the preliminary observations based upon our experience of working with Jatropha for the last three years are discussed. These observations / results will be confirmed over the seasons before making field scale recommendations. These efforts will help identify possible untapped genetic diversity, enhance the potential value through increased use of the available genetic diversity and optimizing productivity through proper silvicultural and agronomic practices in the salt affected lands.

RESEARCH AT KARNAL

Experiments on irrigation, fertilizers, spacing and pruning requirements and intercropping have been laid in one hectare field having semi-reclaimed soil. Soil samples at the start of the plantation revealed that surface soil pH ranged from 7.65 to 8.35 at 0-15 cm and 7.70 to 9.20 at 15-30 cm depths, while lower soil depths (60- 90 cm and 90 -120 cm) had much higher pH up to 10.15 with the range from 8.05 - 10.15. Hard calcareous layer was present at lower depths (90-120 cm) Which varied in its presence and depth across the field. Variability in terms of pH and hard pan layer ($CaCO_3$) was present at the initial soil characterization stage. Low to midium organic carbon (around 0.60 % at surface and 0.20 % at lower depths), low nitrogen and medium P levels occurred in all the profiles. Lower concentration of DTPA Zn and higher concentrations of Fe, Mn and Cu in comparison to critical limits of these micro-nutrients were observed. One year old Jatropha plants were planted in July 2005 using auger hole technology and applying farm yard manure, gypsum & inorganic fertilizers. The original properties of the experimental soil are given in Table-2.

Table-2. Soil pH and EC of different profiles in the field at the start of Jatropha experiment

Depth	Profile 1		Profile 2		Profile 3		Profile 4	
(cm)	pH_2	EC_2	pH_2	EC_2	pH_2	EC_2	pH_2	EC_2
0-15	8.20	1.85	8.35	0.37	8.13	0.30	7.65	0.40
15-30	8.00	1.84	9.00	0.44	9.20	0.56	7.70	0.30
30- 60	7.95	1.95	9.56	0.85	9.90	1.25	7.60	0.26
60- 90	8.00	2.75	9.80	1.12	9.96	1.30	7.65	0.24
90- 120	8.05	0.30	9.70	0.97	10.15	1.61	8.50	0.41

Hard Pan Layer (Kankar)

Alkali / Sodicity Tolerance of Jatropha and Pongamia

Pot studies were conducted to evaluate sodicity tolerance of these species. Different levels of pH were created artificially by adding desired amounts of sodium bicarbonate to soil having pH 7.8 and allowed to equilibrate to achieve uniform and stable levels. Twenty Kg of these soils having pH 7.8, 9.0, 9.5 and 9.8 were filled in 30 cm diameter and 30 cm height porcelain pots and 3-months old and uniform seedlings of Jatropha and Pongamia were planted. Jatropha (Plate-1) and Pongamia perform well up to pH 9.5. Significant reductions in shoot and root growth were observed beyond pH 9.5 in both the species in pots. This indicates moderate tolerance to alkali / sodic stress conditions (up to pH 9.5). However in field situations, Jatropha plants were able to tolerate relatively higher pH and the observed growth reductions were lesser than those observed in pots. It

Plate-1: Pot studies showing Jatropha possesses moderate tolerance to alkalinity (pH_2 ~9.5) was probably due to the fact that the soil in pots was having same level of pH throughout the profile as compared to the field where surface layers had lower pH than the deeper layers. This is also corroborated by the presence of the major proportion of roots in the upper profiles of the soil as almost all the primary lateral roots spread near the soil surface going up to 2 m distances, whereas vertical roots do not go below 60 cm. in low pH and upto 40 cm only at high pH. Number of fine roots and lateral roots are very much restricted in plants growing at higher pH than in lower pH soils. Addition of gypsum and organic manure during auger hole planting in the field studies was helpful in facing sodic stress during establishment stage (Plate-2). This is well corroborated by the

Plate-2: Root growth in lower pH (Left) and higher pH (Right) fields

Pongamia pinnata

Plate-3: Pot studies showing Pongamia possesses moderate tolerance to alkalinity (pH_2 9.5) presence of most of the roots in the upper 50-60 cm soil profile and hardly any roots going below this depth even though the plants were 30 months old. Almost similar tolerance levels were indicated in case of Pongamia (Plate-3).

Use of auger hole and application of gypsum or other amendment along with fertilizers help in establishment and growth of plants in alkali soils having pH 9.5-10.5 and can be helpful in raising Jatropha plantations on such soils. This technology developed at CSSRI has been successfully used in plantation of forest and other tree species for rehabilitation and reclamation of alkali soils.

Weather at Karnal During 2006 and 2007

During the year 2006, a total rainfall of 340.7 mm was recorded, which is the lowest rainfall recorded during the last 34 years since the inception of the Observatory as compared to mean annual rainfall of 743.4 mm. The maximum monthly rainfall of 128.0 mm was recorded in the month of July. During the monsoon, the heavy rainstorm of 41.8 mm was recorded on 9th July. The rainfall of 12.5 mm was recorded in January and there were just 25 rainy days during the year.

The total open pan evaporation during the year was 1492.5 mm and the lowest of 0.7 mm was recordred on 20th December and the highest 12.0 mm was recorded on 15th June. The averages sunshine hours per day were 7.0. The minimum -0.1°C and the maximum 43.0°C temperatures were recorded on 8 January and 8th May, respectively. The highest soil temperatures at 5, 10 and 20 cm soil depths were 50.0°C, 45.0°C and 37.2°C, respectively, on 11th June, 9th June and 7th July, respectively. The lowest values at the same depths were recorded as 2.0°C, 5.0°C and 9.2°C on 8th January only. The highest and lowest vapour pressure values were 27.4 and 4.1 mm of mercury column on 24th August and 8th January, respectively.

During the year 2007, a total rainfall of 761.8 mm was recorded as compared to mean annual rainfall of 743.4 mm (for the last 35 years). The year was a wet year and the annual rainfall was the highest among the last six years. The maximum monthly rainfall of 216.0 mm was recorded in February, which was the highest monthly rainfall in February ever recorded at the observatory since 1972. Three days consecutive heavy rainfall of 61.0, 99.0 and 22.8 mm occurred on 11, 12 and 13 February 2007 (total 182.8 mm) and it also significantly reduced the irrigation demand. There were 36 rainy days as compared to 25 during the last year (2006).

The total open pan evaporation during the year was 1628.3 mm. The average sunshine hours per day were 7.5. The minimum 0.8°C and the maximum 45.0°C temperatures were recorded on 12 January and 10 June, respectively. The highest soil temperatures at 5, 10 and 20 cm soil depths were 48.0°C, 44.0°C and 39.0°C, respectively, on 10 June only. The lowest values at the same depths were recorded as 4.9°C, 8.0°C and 11.8°C on 12 January, 12 January and 1 January, respectively. The highest and lowest vapour pressure values were 28.0 and 4.1 mm of mercury column on 8 August and 4 January, respectively. The monthly weather parameters recorded at agro-meteorological observatory, CSSRI, Karnal are presented in Table-3.

Table-3. Weather conditions at Karnal

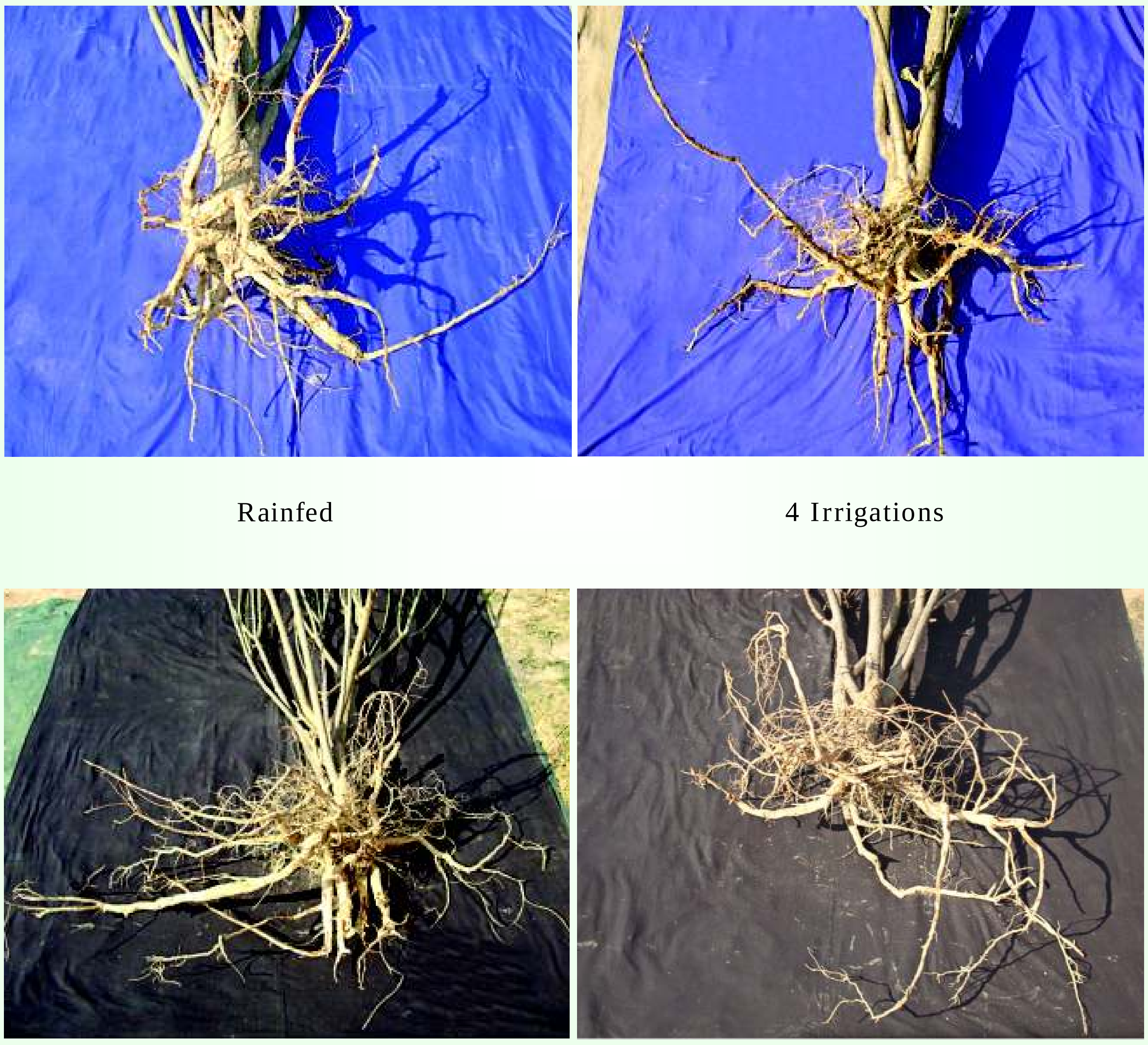
Month	Rainfall*			Evaporation		Sunshine	Wind
	Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month	(hrs/ day)	speed (km/hr)
Jan.	14.4	2	10.4/31	1.6	48.8	6.9	6.6
Feb.	216.0	5	99.0/12	1.9	54.0	5.6	3.2
Mar.	60.3	3	32.8/13	3.6	111.6	7.9	4.0
Apr.	0.0	0	--	6.9	206.7	9.7	3.6
May	7.2	1	06.0/27	9.2	284.6	9.0	6.3
Jun.	108.9	5	40.4/17	8.6	257.4	8.1	7.9
Jul.	100.3	6	40.4/16	5.4	168.5	6.7	5.5
Aug.	133.1	8	50.4/13	4.8	149.4	6.7	4.6
Sept.	119.0	6	57.6/22	3.8	111.1	8.6	2.9
Oct.	0.0	0	--	4.0	122.9	8.0	2.3
Nov.	1.2	0	--	2.0	60.9	6.4	1.7
Dec.	1.4	0	--	1.7	52.4	6.0	3.0
Total	761.8	36	--	53.5	1628.3	89.6	51.6
Average	--	--	--	4.5	135.7	7.5	4.3

Irrigation

Irrigation and fertility are important factors in determining optimum productivity of Jatropha in semi-arid and salt-affected soils. The following irrigation treatments were imposed:

I_0- No irrigation (Rainfed)
I_1- 2 irrigations (Life saving- May/June (Extreme heat wave) & Dec. /Jan.(Frost) / year
I_2 - 4 irrigations / year
I_3 - up to 8 Irrigations / year

Preliminary results over two years show that application of at least 2 crucial irrigations i.e. during peak summer (May-June) and peak winter (Dec.- Jan.) seasons is essential for optimum survival and productivity of Jatropha in the first two years. An additional irrigation during flowering period is helpful, in case rains fail. Applying irrigation before the expected frost is helpful in overcoming the injurious effects of frost. Effects of different irrigation schedules on various growth parameters of Jatropha after 10 months of planting are reported in Table-4 and Plate-4



Rainfed   4 Irrigations

2 Irrigations   6 Irrigations

Plate 4. Effect of irrigation treatments (0, 2, 4 and 6 irrigations) on root growth of two and a half year old Jatropha plants

Table-4. Effect of irrigation on plant growth parameters of two and half years old Jatropha plants growing in semi-reclaimed alkali soil (Each value is the mean of 12 observations)

No. of irrigations	Plant height (cm)	Canopy spread (cm)	Branch or stem diameter (cm)	No. of branches per plant	No. of fruiting branches /plant	No. of fruits/ plant	Fruit weight (g)/plant
0	292	198	4.97	27	10	72	352
2	275	212	5.14	29	13	98	457
4	311	234	5.37	30	16	221	670
6	301	228	5.53	31	12	167	639

Fertilizers

Though Jatropha is reported to be adapted to low fertility sites and saline soils, better yields can be obtained if fertilizers are added. Supply of inputs in terms of organic and inorganic fertilizers promote better establishment of plantation, plant growth and seed yield. Studies were conducted to see the effects of fertilizers with the following treatments:

F_0 Control
F_1 NPK (50 g Urea + 120 g Single Super Phosphate (SSP) + 20 g Muriate of Potash (MoP)/plant
F_2 2 Kg. FYM/plant
F_3 NPK + FYM (F1+F2)

In addition, application of mycorrhiza also help Jatropha plantations in better establishment, disease protection and yield thus, giving higher vegetative biomass and seed production. Mycorrhiza appears to be effective in promoting plant establishment, plant and biomass growth under alkali/ sodic conditions and protecting against wilt and other fungal diseases.

Genetic Variability and Plant Improvement

Low yields and plant to plant variability is a limitation in Jatropha. Yield variations from a few hundred grams to 2 Kg were observed in the first two years whereas yields from few grams to 12 Kg have been reported in literature in 4-5 year old plants. This indicates presence of genetic diversity for seed yield and is a limitation as well as opportunity for plant improvement efforts as availability of good materials in terms of seed and / or nursery and related infra-structure network for procurement and processing is a pre-requisite for success of such new programmes. However, much more research efforts are required to answer these questions and also to come up with suitable provenances or lines to ensure proper incomes to farmers and protect national interests.

Establishment of germplasm orchards at Karnal and Bharuch is an effort in this direction which will help promote further efforts in plant improvement. Thirty six lines/ selections of Jatropha have already been collected from different areas and sources besides identifying 'candidate plus trees' for higher biomass and seed yield. All these collections have been planted in germplasm orchards for further evaluation and salt tolerance. Two contrasting genotypes showing poor and good growth are shown in Plate 5, 6 and 7. These materials have been collected Jatropha lines / varieties from

Plate-5: Views of germplasm orchard of Jatropha at Karnal

Plate-6: Fruit bearing in 1.5 year old Jatropha plants growing in a semi-reclaimed alkali field

Plate-7: Slow Growth- No Fruiting; Good Growth and Fruiting

Tamilnadu, Andhra Pradesh, Gujarat, Rajasthan, Haryana and Chattisgarh. Further efforts are being made to strengthen this collection and also procure non-toxic and edible lines from Mexico and Latin America.

Late formed flowers do not develop into fruits

It was observed that early flowering varieties i.e. July to early September flowering are more suitable for the North Indian conditions where night temperatures start falling during the month of October. Flowers in the late flowering varieties formed later due to indeterminate nature of flowering are not able to develop properly because of availability of lesser time for fruit development and further lower temperatures prevailing during that phase hamper these processes (Plate-8). Consequently, fruits developing out of the later formed flowers either abort or are relatively much smaller thus, leading to lower yields. Indeterminate flowering over prolonged periods is thus a limiting factor in the productivity of Jatropha in North India.

Plate-8: Photo showing poor or no development of fruits from the late flowers

Pruning

Some reports indicate pruning to be a useful practice for obtaining better yields in case of Jatropha. It is generally recommended to prune upper two-third portion of the branches (Plate-9). This was done in Feb.-March after leaf fall and seed harvest in Karnal conditions. Newly formed branches produce side shoots for better sprouting, flowers and seed. In Gujarat conditions, pruning needs to be done by mid-November. The cleanly cut top produces 8-12 side branches. It is a good practice which help in restricting the plant canopy to heights of 2.5 meters for convenient seed harvesting. In the subsequent years, the lateral branches are cut back during the dormant period so as to give a bushy shape to the plant. In addition, more than 10- 15 kg fresh biomass becomes available per plant every year as a result of pruning. Thus, 16.67 to 24.90 tonnes fresh biomass can be obtained with normal 2x 3 m planting having 1666 plants per hectare which can provide 5 to 9 tonnes of dry sticks

Plate-9: Two year old Jatropha plantation showing good growth and biomass 5 months after pruning

Plate-10 : Dried bio-mass after pruning of one and a half year old Jatropha plants which can be used as fuel for domestic use in rural areas (Plate-10). The fresh biomass can also be used in the gassifier to generate energy / Electricity.

Spacing Requiremenst:

Experiments to work out optimum spacing requirements for Jatropha in a semi-reclaimed field were also conducted. Row to row spacing of 3m was tried in combination with 2, 3 and 4 m plant spacings having 1666, 1111 and 833 plants per hectare. Plant growth and biomass of different plant parts two and a half years old plants under different spacings are shown in Table 5 and Plate-11.

Table 5. Fresh biomass of plants and plant parts (Kg) of two and a half year old Jatropha plants (9 month after pruning) under different planting densities

Plant part	Spacing			
Weight (Kg)	3 x 2 m	3 x 3 m	3 x 4 m	Mean
Shoot	12.70	29.00	54.33	32.01
Roots	4.00	8.90	13.30	8.73
Leaves	1.06	1.21	2.21	1.49
Total Plant	17.80	39.15	69.82	42.26
Mean	8.89	19.57	34.92	-
CD at 5%	Spacing-2.93, Plant parts-3.38, Spacing x Plant parts-5.86			

Plate-11: Photograph of the two and a half year old Jatropha plants showing the effect of different spacings (2x3 m (a), 3x3m (b) and 4x3m (c)

Intercropping

Intercropping with other value-added crops, particularly low water requiring crops including aromatic and medicinal plants can be an option which provides additional income to the farmer during the initial years. Optimum yields in case of Jatropha are reported from 3 to 5 years and is longer in case of Pongamia where fruiting starts around 5 years. To evaluate this option studies involving moong, mustard, dill, turmeric, tulsi, and matricaria as intercrop with Jatropha were carried out in different agro-climatic and soil conditions. Since Jatropha can be grown as block plantations, row fences or in combination with the agricultural crops, there is a need to test such plantation models in field so as to optimize yields for adaptation by the farmers and entrepreneurs.

Specific intolerance with these crops was not detected when intercrops were sown in Jatropha or Jatropha and Pongamia plantations. On the contrary, the shade can be exploited by shade-loving plants. Indian mustard gave a seed yield of 1.08 t/ha providing Rs. 26,000/ in addition to Jatropha seed, when planted as an intercrop between Jatropha and Pongamia plantations on a semi-reclaimed alkali soil. Similarly, dill *(Anethum graveolens L.)*, a moderately salt tolerant spice crop forms a good proposition for intercropping with Jatropha on Vertisols with sub-surface salinity and irrigated with saline ground water(Plate-12). While, Jatropha produced 2.45 q/ha seed, dill produced 670 kg of seed/ha. Gross returns from dill when intercropped with Jatropha worked out to be Rs. 23000/- per hectare.

Plate-12: A view of the mustard intercrop in Jatropha and Pongamia plantations

STUDIES AT BHARUCH, GUJARAT

Response of Jatropha to Salinity and Saline Water Irrigation

Studies showed that Jatropha grows and performs well in soils having salinity up to 10 dS/m. Similarly, Jatropha plants irrigated with saline ground water (11.6 dS/m) on Vertisols with sub-surface salinity also indicated good response in terms of growth, flowering and seed production (Table-6)

Table 6. Effect of saline water (11.6 dS/m) irrigation on seed and oil yield of Jatropha on saline Vertisols second year plantation (1111 plants/ha)

Irrigation frequency (days)	Irrigation water applied (l/plant)	Plant height (m)	Seed yield (g/plant)	Seed yield (kg/ha)	Seed oil content (%)	Seed oil yield (kg/ha)
10 (6)	90	1.36	268	2977	35.2	1047.9
20 (3)	45	1.22	184	2044	36.2	739.9
30 (2)	30	1.14	173	1911	36.3	693.7
CD at 5%		0.06	8.54	15.57	NS	10.53

(Figures in the parenthesis indicate number of irrigations)

Plants irrigated with saline water at three different intervals i. e. once in 10, 20 and 30 days indicated that there was no significant difference between 20 and 30 days irrigated plants in terms of growth and seed yield.

This suggests that marginal quality of saline ground water can be saved if the crop is irrigated during hot summer once in a month. Though only a marginal decline in seed yield occurred in plants irrigated by saline water at 20 or 30 days, by foregoing this seed yield loss, there can be a saving of marginal saline water by 50-66 per cent. Application of lesser quantities of saline water also reduces salt build up in the soil.

Tolerance to water stagnation / water logging

Jatropha is well known for its drought tolerance and can survive dry conditions. It will also stand for long periods without water and surviving on whatever little rains, if available. However, in order to get optimum yield, irrigation is required. The observations at Samni farm, Bharuch in Gujarat indicate that the plants can also withstand water stagnation for 2-4 weeks on saline Vertisols without any mortality (Plate-13). Contrary to the general feeling that Jatropha cannot withstand water

Plate-13: A field view of water stagnated Jatropha plants at Samni farm, Bharuch (Gujarat)

stagnation, we noticed no plant mortality even after waterlogging for 2-4 weeks. Further studies to evaluate tolerance to waterlogging in the germplasm available and the mechanisms governing the responses are underway.

LIMITATIONS AND CAUTIONS

Despite several usefull characteristics, the full potential of Jatropha is far from being realized. There are several reasons and issues: technical, economic, cultural and institutional - that need further intensive research, discussion, formulation of policies and creation of proper infra-structure. There is a need to be sure about all aspects of Jatropha, especially its effect on environmental ecology and humanity as some reports indicating possible harmful effects have appeared. Authenticity or validity of such reports needs to be looked into properly in a scientific and rational manner. Due to its wide adoptability to different stress conditions, Jatropha can spread as a weed raising possible environmental concerns. Evaluation for various diseases and pests in large plantations or monoculture through higher inputs like irrigation and fertilizers is also a priority.

A National Workshop was organized by Planning Commission & ICAR in New Delhi on Feb. 1, 2008 under the chairmanship of Prof. V. L. Chopra, Member, Planning Commission. Major recommendations were that research activities related to genetic improvement, crop management and development of high-yielding varieties for specific conditions and regions may be conducted on priority. Jatropha cultivation may be taken up on wastelands only in the country. This recommendation is important in view of the projections and estimates suggesting that 12 million hectares of land will have to be brought under biofuel crops to meet the target of meeting 10% of total transport fuel with biofuels by 2017.

Some varieties of Jatropha from Mexico and Latin America are reported edible in nature as their seeds are used for eating after roasting and oil is also used for edible purposes. We are trying to procure such materials for introduction, evaluation and plantation in India.

Proper planning and coordinated efforts on the part of governments, researchers and farmers might ensure that fields of Jatropha and other abundant oil trees and crops will stand alongside oil fields in meeting the growing emphasis the world over on renewable energy sources., accompanied by rising crude oil prices and uncertain world supply position are likely to provide a favourable scenario to the benefit of Jatropha and other bio-diesel crop growers. However, there is a strong case to intensify research efforts to develop sustainable technologies to make Jatropha and Pongamia a viable bio fuel industry before making large scale investments.

CONCLUSIONS

Irrigation and fertility are important factors in determining optimum productivity of Jatropha in semi-arid and salt-affected soils. Application of at least 2 crucial irrigations i. e. during peak summer (May-June) and peak winter (Dec.- Jan.) seasons is essential in the first two years for optimum survival and productivity. An additional irrigation during flowering period is helpful, if rains fail.

- Jatropha plants have good potential to produce biomass for fuel and other purposes and yield significant leaf litter to improve soil quality. These are additional supplementary benefits.
- Pot studies on Jatropha and Pongamia indicate moderate alkali tolerance up to pH_2 9.5. There is a need to evaluate more germplasm to identify more promising /salt tolerant lines.
- Field and other studies show good salt tolerance of Jatropha during establishment period as not much reductions occurred in soil salinity of 10- 12 dS/m and application of saline waters.
- Low yields and plant to plant variability is a limitation. Yield variation from a few hundred grams to 2 Kg was observed in the first two years in a semi-reclaimed alkali soil.

- This confirms the presence of genetic variability in the germplasm thus offering scope for plant improvement efforts. Establishment of germplasm bank will help further efforts in improving productivity
- Early flower initiation (July -Aug.) is a desirable trait in the North Indian conditions as late formed flowers and late flowering varieties face lower night temperatures thus, hampering further seed development and maturity.
- Pruning after seed harvest and leaf fall help promote biomass, flowering and seed production in the following season besides providing 16.67 to 24.90 tonnes of fresh biomass every year which can be used as a domestic fuel after drying and can also be used her conversion into bio fuels with the newer technologies becoming available.
- Plants raised through vegetative propagation show early establishment, flowering and seed yield and are also relatively more uniform than the plants raised from seeds.
- Applying irrigation before the expected frost helps in overcoming injurious effects of frost on plants. Occurrence of frost in north Indian states is a limiting factor for Jatropha cultivation.

These conclusions are based upon our experience of working with Jatropha and Pongamia for the last about 3 year. Further observations and testing will continue to make final recommendations.

FUTURE SCENARIO

There is a need to examine the potential role that Jatropha can play in meeting some of the needs for energy services for rural communities, creating avenues for greater employment and its overall role in the national energy scenario.

Keen interest and initiatives by Central and State governments and some major private companies in taking up major plantations is a good forerunner in this direction and holds much promise with lot of benefits for future.

Some varieties of Jatropha from Mexico and Latin America are reported edible in nature as their seeds are used for eating after roasting and oil is used for edible purposes. Efforts are being made to procure such materials for introduction, evaluation and plantation in India.

Proper planning and coordinated efforts on the part of governments, researchers and farmers might ensure that fields of Jatropha and other abundant oil trees and crops will stand alongside oil fields in meeting the world's future energy needs providing a much-needed boost to rural economies around the world. More emphasis need to be given to harnessing use of other bi-products like available biomass with potential use as a domestic fuel and as a source for bio-energy besides other multiple uses like addition of leaf litter, honey bee keeping, silk worm rearing and other medicinal uses. These value additions will make it a more productive and competitive system. The growing emphasis and interest the world over on renewable energy sources, accompanied by rising crude oil prices which has touched 118$ per barrel and uncertain world supply position, are likely to provide a favourable scenario to the benefit of Jatropha and other bio-diesel crop growers.