Henna

Cultivation, Improvement and Trade

Central Arid Zone Research Institute
Jodhpur

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Foreword

Henna (*Lawsonia inermis*), popularly known as mehndi, is a perennial shrub indigenous to North Africa. The plant has been introduced widely throughout the tropics and sub-tropics as an ornamental (frequently as a fragrant hedge), and as a commercial crop. Since ancient times henna leaf powder has been employed as a cosmetic dye for hair, skin and nails and it has acquired a particular significance in Islamic culture. Prior to the widespread availability of the synthetic dyestuffs, henna was also employed as a dye for textile and leather. More recently, there has been an increase in its usage as a natural hair dye in Western Europe and North America. In India it is used as cosmetic for application on hands during festivals and religious occasions. The essential oils extracted from henna flowers are used in perfume industry. There is strong evidence that henna use on large scale originated in Egypt and Egyptians, Jews, Persians and Turks were not only the ones to use henna extensively but also caused it to spread throughout the Middle East and beyond. It is emerging as important item for diversification of livelihood opportunities.

At present Sojat and adjoining regions of Pali district in Rajasthan contribute over ninety per cent of henna production in the country. Of the total produce about 30 per cent is exported and India is the largest exporter of henna. It is thus important that there should be integrated efforts to understand and improve all aspects of this crop starting from nursery raising, cultivation, trading, processing and marketing. The NATP programme on improvement of shrubs and workshop held on "Issues and prospects of henna production and trade in arid and semi-arid region" at Sojat on 26th September 2004 was a right step forward. The effort to compile the outcome of work done at the Institute, interactions during workshop and research information available in the country as contributed by the participants of the workshop is therefore praiseworthy and timely. I hope that it will benefit all the stakeholders associated with henna to promote this important perennial crop in arid and semi-arid areas.

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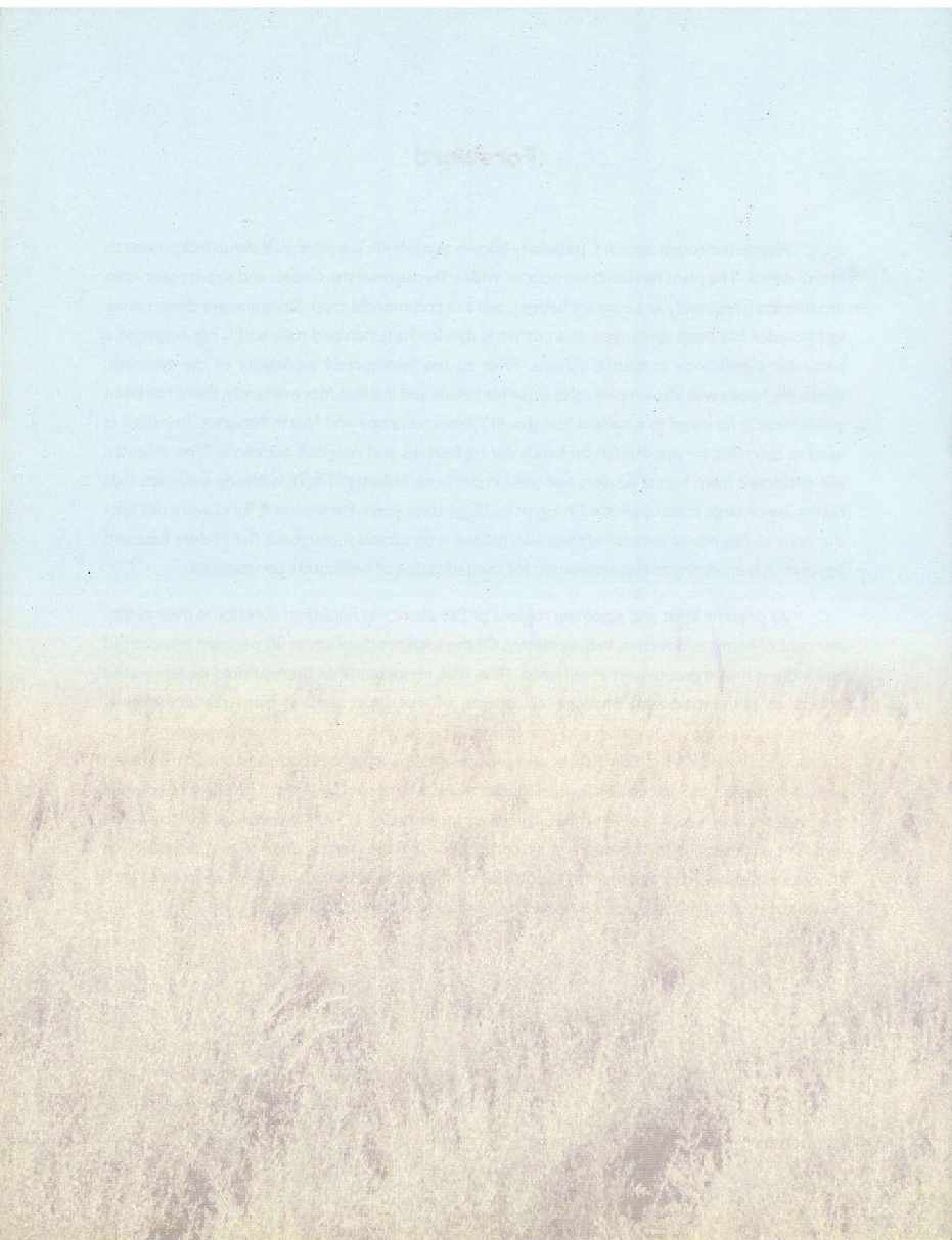


Preface

The earliest dyes used by man were derived from plants or animals and the principal ones included saffron, henna, logwood and cochineal. With passage of time the dyes of synthetic origin gradually replaced most of the natural dyes. However, the use of henna has persisted as a cosmetic and hair dye. There are four distinct benefits of henna application, called the 'four C's'. It cools, conditions, cleanses and colours. It also protects the skin by blocking harmful UV rays. Henna was also employed as a dye for textile and leather. The essential oils extracted from henna flowers are used in perfume industry. In addition henna is known to have medicinal uses for skin diseases, liver problems and has antifungal, antibacterial, and nematicidal properties. Globally, the overall consumption of henna is stated to be high in the Middle East and Asian countries, where various cultural groups have a long tradition of using henna. It is likely to grow further with the increase in population in this region. In India, the use of henna is particularly visible during festivities and social occasions.

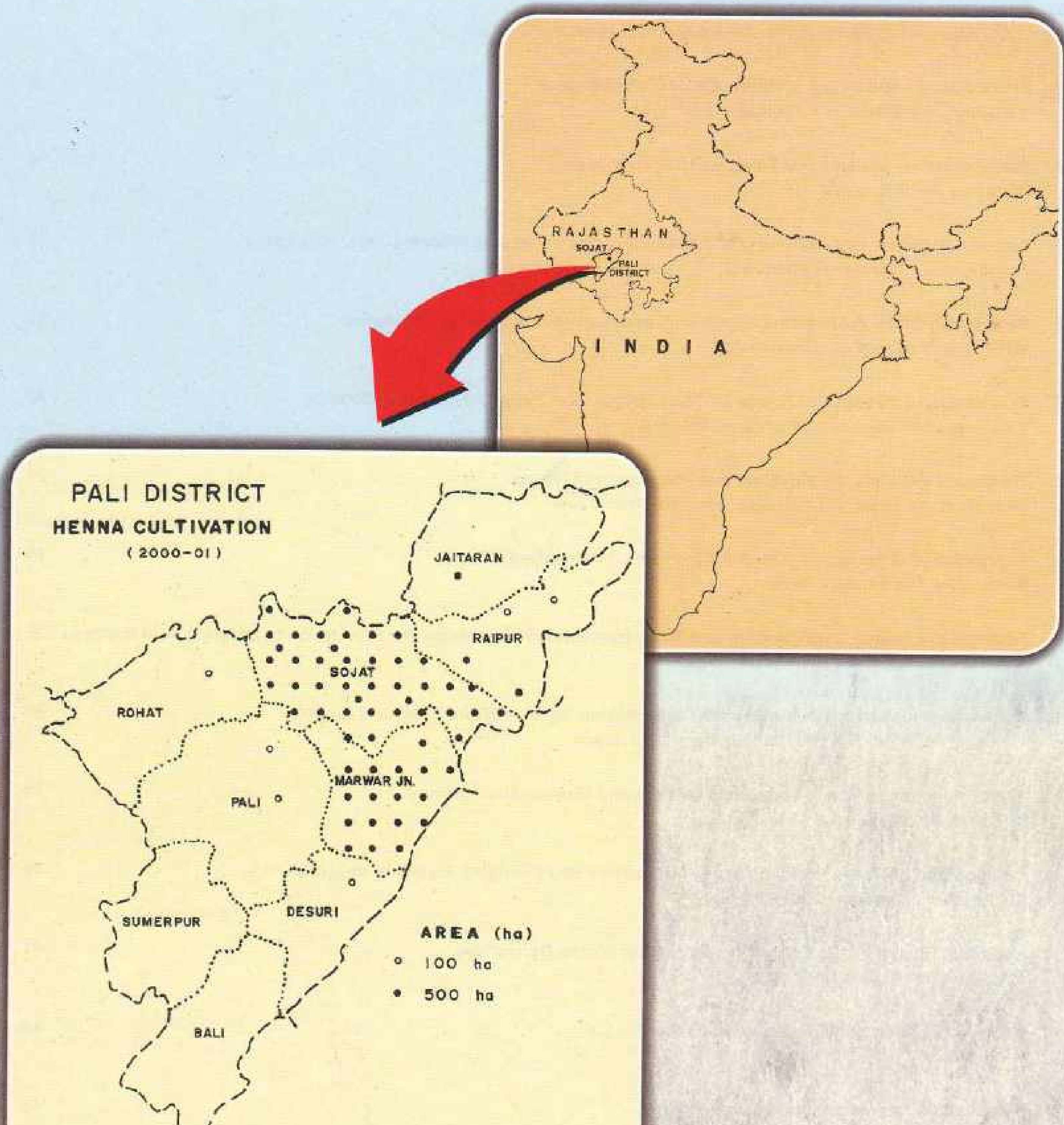
Although the henna plant is distributed throughout the tropics and sub-tropics, it is grown mainly under hot climates. It is cultivated in over 22 countries across Asia, the Middle East and Africa. In India, henna cultivation is presently concentrated in the arid fringes in parts of Sojat and Marwar tehsils of Pali District of Rajasthan. Commercial cultivation of henna in this region is supposed to have begun about ten decades back in the villages Saiwaj and Somesar near Sojat (Pali). Fifty years ago the contribution of Rajasthan to the national production was less than five per cent. Last fifty years have seen a major transformation in Sojat region that presently accounts for over ninety per cent of the production of the country. In 2003-04 the henna plantations in Sojat and surrounding areas of Pali district covered an area of about 34,000 ha. Additional henna producing areas in the country include Bilara, Palasni and Mathania in Jodhpur district and Chamundia in Nagaur district of Rajasthan; and Nimach in Madhya Pradesh and Bordoli (Surat) in Gujarat. The total production of henna dry leaves in the country during 2003-04 was estimated to be 39,000 tonnes based on the average productivity and acreage. In terms of total trade, India is currently the largest exporter of henna. It is the major supplier to the Middle East market followed by Pakistan, Sudan, Iran and Egypt. During 2003-04, an estimated 25,000 tonnes henna powder was sold within the country for domestic consumption.

The development of henna cultivation and processing in Sojat is a blend of indigenous knowledge and people's innovations. It has lead to overall development of the region through new avenues in trading, processing and marketing. Henna cultivation in the region is rainfed with no use of fertilizers or pesticides. The value of henna from this region is because of this pattern of cultivation being followed by the farmers since decades. As the cultivation spread, people of the region faced new challenges. There is thus need for understanding the problems associated with this crop and adopt scientific approach to solve the problems related to nursery raising, plant protection, soil & water management, harvesting, quality testing, post-harvest storage and processing.

An NATP workshop on "*Issues and prospects of henna production and trade in arid and semi-arid region*" was organised on 26 September 2004 at Sojat - the centre of all activities related to henna. The present compilation is the outcome of the interaction among farmers, traders, industrialists, state officials from line departments and scientists from various research organisations during the workshop, research done at the Institute during last decade and contributions provided by various participants. We thank Dr IP Abrol, Chairman Scientific Advisory Panel, NATP (arid ecosystem), Dr BS Chundawat, Vice Chancellor SDAU, SK Nagar, Gujarat, Dr HP Singh, Ex- Director CRIDA, Hyderabad and Sh. D.P. Sharma, Director Horticulture, Jaipur for leading these deliberations. We would also like to thank all the staff members of State department of Agriculture, farmers, trading community and Industrialists for their active cooperation and interest in the workshop. We would like to thank M/s Milan Mehndi for organising visit to their factory for on the spot understanding of issues and various steps involved in henna processing. The impetus provided by SAP, AED and PPSS, NATP (arid ecosystem) for organising this workshop and financial support for printing the proceedings is acknowledged.

Editors

CONTENTS



Area under Henna in Pali District of Rajasthan (2000-2001)

Production, Trade and Future Prospects of Henna

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Henna is an important dye plant under cultivation in India, Pakistan, Sudan, Iran, Yemen, Moracco, Niger, Egypt, etc. In India over ninety per cent of the henna production comes from Sojat region of Pali district of Rajasthan (map, opposite page). Henna, commonly used as cosmetic for dyeing hair and palms or feet, has been one of the important plants since ancient times and has been in use for it aromatic and medicinal properties. This is possibly the oldest cosmetic still in use. The increasing trend of using herbals has contributed to increase in demand of henna all over the globe.

There is no reliable estimate of the global production of henna perhaps because henna is a minor commodity of international trade. Many Islamic countries in the Middle East and North Africa cannot meet their high requirement from domestic production. These and other non-producing countries buy substantial quantities of henna from other countries. During 1988-93 the average volume of world trade in henna leaves, either powdered or whole, was at least 9,000 tonnes per annum (Green, 1995).

Saudi Arabia has been the largest importer in the Middle East region (imported about 3,000 tonnes in 1992-93) while the major importers in Europe were France, UK and Germany. The Eastern European countries together imported around 500 tonnes per annum during 1970s and 1980s (Green, 1995). Some countries have traditional suppliers. Yemen and Nigeria traditionally export their henna to, respectively, Saudi Arabia and Algeria.

India exported 4,500 to 7,600 tonne henna per annum during the period 1988-93 (Green, 1995). In the year 2002-03 the country exported 2,383 tonne henna as powder to Turkey, UAE, USA and several countries (Table 1) and 150 tonne as leaves, mainly to the Middle East countries. Besides these, considerable and much higher amount of henna is exported as henna dye, henna based hair care and cosmetic products according to a henna industrialist (Prajapati, 2004, personal communication). Present estimate of the henna export, in all forms, would be around 10,500 tonnes in 2003-04 assuming that 70 per cent of total production in the country is consumed in the domestic market and the rest is exported. It is estimated to be worth at least Rs. 91 crore at the average price US $1870 per tonne of Indian henna powder exported during 2002-03.

There is little information available about future demand and supply position of henna in the world. However, it is considered that the growth of demand would be steady in the Middle East and Asia. In Western Europe and USA where there was a rapid growth in henna usage during the 1970s and 1980s the demand position has more or less stabilised and there has been a plateauing of growth subsequently. Some scope of higher growth is expected in the Eastern Europe region.

The henna trade in India is apparently growing at an average annual rate of about nine per cent. The sale of dried henna leaves at the exclusive henna market at Sojat (Pali) during 1995-2003 increased from 10,264 tonne to 24,744 tonne. Henna leaves worth Rs. 65 crore were traded here during 2003-04. The world price of powdered henna from India during 1992 was approximately US $ 700 per tonne (Green, 1995). It has now reached a level of US $1870 per tonne (Table 1) indicating the high demand of Indian henna in export market.

Table 1. Export of henna powder (2002-03)

Country	Qty (kg.)	Value (Rs.)	Per cent of total export
Turkey	579510	23030170	24.32
UAE	232841	37321644	9.77
Turks CIS	218300	5349780	9.16
USA	165517	12328434	6.95
Japan	123912	28067141	5.20
Saudi Arab	120900	7463270	5.07
German F Rep	112445	7126327	4.72
Syria	102370	3588959	4.30
France	98950	3603147	4.15
Malaysia	70525	6257358	2.96
Sub-total	1825270	134136230	76.59
Others	557829	71940065	23.41
Total	2383099	206076295	100.00

Source: Monthly Statistics of Foreign Trade of India (2002-03), DGCI & S, GOI.

Issues and Future Prospects

In view of the growing demand of henna as a safe cosmetic dye, the importance of cultivating and producing adequate quantity of henna leaves for future is evidently beyond doubt (Fig.1). And for maintaining India's dominance in the world henna market concerted efforts are required to further improve level and quality of henna leaf production.

Fig. 1. Leaf samples of promising collections of henna on display during exhibition at Sojat

Cultivation of henna is profitable under low rainfall conditions and is an important source of income of farmers in the drought prone arid and semi-arid regions. At 2003-04 price level henna farmers earned a profit of Rs. 12,450 per hectare on an average. Other benefits associated with henna cultivation include drought proofing, improved land use through sustainable forestry (henna plantations have an average productive life of about 15 years and come under short rotation forestry practices) and economic use of marginal and gravely lands or wastelands. It also helps reduce soil erosion in the arid regions in particular due to deep root system and perennial nature of henna plantations. Thus there are adequate benefits for promoting henna cultivation for the economic and ecological development of the hot dry tracts of the country.

Henna is cultivated in dense plantations as an annual ratoon crop. One to two leaf harvests are taken every year depending on growth. However, due to the extensive nature of cultivation and low use of inputs (more than 90 per cent of henna in Pali is rainfed and use of fertilisers is almost nil) there is risk of losing productivity in the long term. There is need to develop scientific management techniques for achieving sustainable and higher yield level from our henna plantations (Fig. 2).

Fig. 2. Scientific advisory panel members in a rainfed field being harvested by the family members of a small grower

To boost the production of henna and its trade in national and international market there is need for better understanding of problems at various levels and finding their joint solutions through combined efforts of farmers, businessmen and industrialists. A research study was conducted during 1999-2004 through sample surveys among henna growers. In addition, an NATP workshop on 'Issues and Prospects of Henna Production and Trade in Arid and Semi-arid Region' was held at Sojat on 26" Sept. 2004 for this purpose. The deliberations were lead by chairman and members of Scientific Advisory Panel (SAP) of NATP (arid ecosystem) (Fig. 3).

Fig. 3. SAP members leading the deliberations during NATP workshop

The interaction group included growers, traders, industrialists involved with henna, officials from State Departments of Agriculture, Horticulture, and Industry, scientists from Rajasthan Agricultural University, Gujarat Agricultural University, CAZRI, Jodhpur and its Regional Stations at Pali, Jaisalmer & Bhuj, and CRIDA, Hyderabad. It was felt that there is need for extending the area under henna, increasing productivity per unit area through better management and selection of high yielding genotypes and enhancing the value added components for higher earning of foreign exchange. Sojat being major henna production area, should receive the prime attention and be developed as centre of excellence by focusing R&D efforts in this region. Problems related to cultivation need to be addressed systematically. The interaction with the henna growers, traders and manufacturing partners during the workshop revealed the need for scientific approach for nursery raising, plant protection, soil management, harvesting, quality testing, post-harvest storage and processing. Various issues raised by farmers/traders/ industrialists and possible solutions that emerged from the discussion among participants are :

Seed germination in nursery requires 10-15 days of soaking

Sojat was traditionally a cotton growing area. It has now shifted to mehndi for the last 40 years or so. But farmers still follow traditional seeding of mehndi. Mehndi seeds are soaked in water for 10-15 days and then sown in the nursery. Thereafter the plants in the nursery have also slow growth. There is thus a need for some seed treatment for ensuring early germination and rapid growth. Scientists informed that the germination and soaking time can be reduced by using salt or scarification using acid.

Termites at the time of sowing as well as in established stands are a major problem

Scientists informed that friendly fungi (*Metarrhizium* and *Beauveria*) are being developed for control of termites. The fungus is applied to soil and it spreads along with the roots. It infects the termites with a transmittable disease resulting in spread of this fungal disease in all the termites in the entire colony ultimately killing them. It will be better if this fungal powder is mixed with FYM and then applied with the onset of rains. The technique is under testing. Even though chemical methods are available, many of the speakers supported use of biological methods and other ITKs. It was opined that innovative biological methods for termite control need to be studied. For example, if ants (by applying gur [sugar] are left in the fields these will eat away all the termites as had been tried in Maharashtra. Spraying of kerosene on termitorium will also kill the termites specially when it looks slightly wet. If we are able to put lantern for 2 hours in the henna fields in the evening, especially during rainy season all the flying termites will get attracted towards it and eventually get killed. In the pitcher, a hole is made at the bottom and filled with maize cobs after removing the corns. This pitcher is placed in the field. Termite will be attracted to eat these cobs and when it is full of termites it should be taken out and thrown away/destroyed. These were some of the ITKs talked about in the inteaction meeting and need to be evaluated on farmers' fields. Reasons for higher termite attack in some pockets also needs to be studied. One of the farmer narrated the experience of use of chemical methods for termite control where the termite powder mixed with coarse sand was spread in the field and this sand acted as very good carrier.

Semiloopers are major pests damaging the crop during rainy season (Fig. 4)

A few farmers desired that aerial spraying as is done for cotton may be adopted in henna during epidemics whereas few others expressed the view that chemicals are not desirable as the value of henna is because of its organic cultivation. One of the participants narrated the experience of using shallow baskets on trees where bajra (pearl millet grains) is put every day to attract birds. This served as a useful biocontrol measure as the birds prayed on the loopers. There is need for finding and removing alternate hosts and develop other biocontrol methods.

Fig. 4. Semilooper damaging henna crop

Henna quality is variable in different pockets, soils in some pockets are hard and absorb less water than required and irrigation decreases dye content

Farmers informed that in some pockets quality of mehndi is better than the other pockets and hence there is need for detailed soil survey and identify the parameters associated with dye content and yield. One of the farmers narrated the experience that addition of gypsum helped in improving soil quality and increasing water absorption. There is need for quantifying gypsum requirement, providing subsidy and developing deficit irrigation strategies for obtaining quality product and higher yield. This information will be helpful in spread of henna to other arid and semi-arid regions. Mehndi from drier regions has 40-45 kg leaves per 'bora' (jute bag made by stitching two standard bags) whereas in irrigated field it accommodates 30-35 kg leaves per 'bora', hence application of irrigation needs to be standardized. Organic manures should be used for henna. Also need for study of salinity tolerance in this region.

Leaf shedding at base near maturity causes loss of yield and forces harvesting even when conditions are not favourable for harvesting (Fig. 5)

There is leaf shedding at the base of plant near the harvest period, particularly if harvesting gets delayed due to late rains. As a result farmers are sometimes forced to harvest the crop despite unfavourable weather. It was desired that techniques/varieties should be developed to improve persistence of leaves so as to have intact green leaves till the harvesting of crop. Hence, need to breed cultivars and develop agrotechniques, balance nutrition, biofertilizers, hormones and workout other physiological requirements so that plants may bear green leaves for longer duration. Variation in maturity in different plants in the farmers' fields has been observed and hence there is scope of selection for this trait. Gibberellic acid treatment has been shown to increase vegetative growth and lower seed production (Devedjyan *et al.*, 1987).

Fig. 5. Leaf shedding at base in mature plants of henna

South westerly winds combined with moisture stress induce early flowering resulting in reduction of yield

Such winds were reported to decrease yield to the tune of 50-60 per cent by the farmers. Efforts are needed to have plants that can withstand this climatic change and can remain green and have delayed flowering. The present practice of collecting seed at random is not appropriate and participatory plant breeding is required for genetic improvement and development of late flowering, high dye containing and better leaf yielding types.

Flowers / berries are generally removed by the farmers as these affect the quality and growth. Berries deteriorate the quality of produce. The seed and berries also have no value in industry and are discarded. (Fig. 6)

Many farmers were of the view that the flowers, that at present are discarded, should be used to make scent. The details of volatile oils in henna flowers like beta-ionone and its derivatives, 2-phenylethanol, etc. are well known (Wong and Teng, 1995) and the scent can be prepared.

To get rid of the berries, it may be desirable to develop fan/winnower for removal of undesirable matter and hence value addition at the farmers' field. Some farmers also expressed the need for developing cultivars free from berries.

Fig. 6. Ladies removing flowers and berries from mature crop of henna

The cost of harvesting henna and weeding as well as transplanting is very high because of higher wages of scarce skilled labour

Most of the farmers felt need for mechanisation for hoeing, weeding and harvesting of henna crop. There is need to standardize methods for weed control, including use of weedicides and also adopting more inter-row spacing for weeding using tractor. At present farmers sow henna at 30 cm row-to-row distance. Experiments at CAZRI Regional Research Station, Pali on spacing have demonstrated that spacing of 45 and 60 cm can be adopted without loss of yield and quality and such plots can be weeded using bullocks or tractors. In addition to the cultural practices it may be possible to use some weedicides at the initial stages. However, their residue analysis will be required to ensure that quality of henna conforms to international requirements. Since most of the mehndi harvesting is done by women using local sickle and leather glove (Fig. 7), there is a need to develop better harvesting tools/machines and some easier harvesting methods. There is also a need for intensive programme for training for henna cultivators by horticulture /agriculture department/ KVKs.

Fig. 7. traditional tools (sickle and leather glove) for harvesting of henna

Even though henna is rainfed crop, rains during harvest or just after it are very harmful as the quality of leaves deteriorates and there is reduction in the market value of the material

Farmers expressed the need for crop insurance for Henna growers. It may be desirable to construct community sheds for storage of harvested material and provide tarpaulin on subsidised rates. If there is a rain or humid weather at the time of harvest, the lawsone content declines. Quantification of lawsone losses is required. There is a need to understand lawsone in different phases of plant growth and role of micronutrients for good growth.

No use of crop residue (branches & stems)

There is need to use residue as such or recycle it in the form of compost. At present these branches are just put on the bunds to raise and stabilize the bunds that are essential for water harvesting or are sometimes used as fuel. Other possibilities of residue management, and their use for moisture conservation also need to be explored.

Fluctuation in market price, determination of price by the purchaser by looking at leaves and assessing quality

Policies should be evolved for fixing minimum support price of henna and purchase should be based on quality, hence need for simple methods for estimating dye content and unwanted materials. Farmers should do some initial processing at threshing site so that the material is free from seed and soil and this simple value addition can fetch better price. Industrialists will appreciate receiving mehndi leaves free from soil particles, flowers/fruits/ seeds as there is about 10-15% debris and its removal incurs extra cost and labour. Such product may fetch better price to farmers and help industry to produce better quality products.

Lack of facilities for chemical analysis of henna in near vicinity affect its export

Industrialists told that export depends on rates in the local markets and production in other countries like Sudan, Pakistan, Iran and Yemen and at times competition is very stiff. Chemical analysis takes 2-3 weeks and is done at Delhi/Bombay. If Sojat is to be developed as centre of excellence for henna cultivation and export /marketing then such facilities should be developed at Sojat/Jodhpur. It however should be ensured that the reports from this lab should find acceptance with the international buyers and it should have legal status. Sojat is emerging as major market of senna leaves as well and the facilities can be used for estimating sennosides in addition to lawsone content and other quality parameters.

Interaction must be continued and farmer groups may be identified and taken to other parts to show exhibitions and other modern agricultural practices. Promotion of on farm research on henna will help in finding ways and means to solve the problems of henna growers, traders and industrialists. More media coverage, specifically designed programmes, films, market intelligence regarding crop situation in competing countries and expected export requirements, better quality controls to check mixing of other plant materials or chemicals, are some other ares requiring urgent attention. All this requires a well defined and focussed policy for production, trade, processing and export of this crop.

Although henna is well known as a cosmetic dyestuff in commerce its importance also lie in the medicinal and other anti-microbial properties of its leaf dye and in the fragrant essential oil extracted from its flowers. There is scope to explore and expand the market of henna for such uses as well. The niche of herbal printing dyes is another area where use of henna leaf dye can be promoted anew in order to further increase the market value of henna leaves.

References

Anonymous 2003. Monthly Statistics of Foreign trade of India (2002-03). Directorate General of Commercial Intelligence & Statistics, Ministry of Commerce & Industry, Govt. of India, Kolkata.

Green, C.L. 1995. Natural Colorants and Dyestuffs - A review of production, markets and development potential. Non-wood forest products 4. FAO, Rome, Italy.

Prajapati, N.D. 2004. M/s Sonamukhi Udyog, Sangaria Fanta, Salawas Road, Jodhpur (*personal communication*).

Devedjyan, H., Khazhakyan, Kh., Mairapetyan, S. and Devedzhyan, Kh. 1987. Characteristics of the effect of gibberellin and retardant CCC on the yield of henna plants in soilless culture. In: *Proceedings of the IV International Symposium of Plant Growth Regulators*, Part 2 (eds. D. Lilov et al.), M. Popov Institute of Plant Physiology, Sofia, Bulgaria, pp. 862-867.

Wong, K.C. and Teng, Y.E. 1995. Volatile components of *Lawsonia inermis* L. flowers. *Journal of Essential Oil Research (USA)*. 7: 425-428.

Present Status and Scope of Henna Cultivation in Gujarat

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Henna, *(Lawsonia inermis* L.) a perennial shrub, also known as "Mehandi" belongs to family Lythraceae and is a native of North Africa and South-west Asia. The plants are glabrous, much branched shrub or a small tree with greyish brown bark. Leaves opposite, sub-sessile, elliptical or lanceolate, entire, acute. Flowers numerous, small white or pink coloured, fragrant, in terminal panicles cymes. Fruit globose, capsule of pea size, seed smooth, pyramidal with hard seed coat. Crop is propagated through seeds. However little is known about varieties. Plant finds importance due to presence of orange-red dye in its leaves and essential oil in flowers. Oil extracted from leaves and flowers called "Otto of henna" is utilized as perfume. The seed oil is used for anointing the body. Paste of dried powder of leaves utilized for dying hairs, cloths and decorating skin. The dry leaf powder is also used in the Indian system of medicine. Beside this, other plant parts also find their use in cure of various ailments as medicine in Ayurveda. It can grow well in arid and semi-arid regions. Many parts of the state may be suitable for henna cultivation. Few traditional pockets of henna cultivation like Bardoli in Surat are still in existence in the state.

About the State

The state of Gujarat covers 6 per cent of the total geographical area of the country. The state has a coastline of 1600 km, which forms the western and south-western boundaries. At the north it forms the international boundary with Pakistan. In the east and the north-east, it is bounded by Madhya Pradesh and Rajasthan, respectively. Maharashtra lies in the east and south-east of the state.

The state has got a total geographical area of 196 lakh ha. As per the latest division, the state is made up of 25 districts and 126 talukas. The biggest district is Kachchh with 45.6 lakh ha area followed by Jamnagar (14.1 lakh ha) and Banaskantha (12.7 lakh ha). Gandhinagar is the smallest district with 0.65 lakh ha. The state has a population of 44 million, which is 5 per cent of the total population of the country.

Gujarat from the viewpoint of physical features is divided into three regions viz. (i) the main land plains extending from the Rann of Kachchh and the Aravalli hills in the north to the river Damanganga in the south; (ii) the hilly peninsular region of Saurastra and rocky and sandy area of Kachchh and (iii) the north-eastern hill tract. The main land is almost a flat plain made up of alluvial soil except for some sandy soil in the north.

The state has 18.9 lakh ha under forest, which accounts for 10 per cent of the reported area, among the different districts as high as 98 per cent of the reported area is under forest in Dangs. Barring Gandhinagar where no area has been reported under forest, the minimum percentage of forest has been observed in Ahmedabad (1.3 per cent), Kheda (1.4 per cent) and Mehsana (2.0 per cent) districts (Table 1).

The gross cropped area in the state is around 112 lakh ha working out to be 59 per cent of the reported area, Banaskantha has got about 90 per cent of area as a gross sown. It is minimum (15.0 per cent) in Kachchh district, which may be due to the fact that almost 3/4th of the district is either barren or cultivable fallow because of scanty and erratic rainfall (Table 1). Kachchh, the largest district with an area of 45652 km^2 in the north-western part of Gujarat state, is situated along the great Indian desert and Rann of Kachchh. The district derives its name from the shape of land boundaries which resemble the inverted tortoise called "Kachhappa" in sanskrit. The crescent shaped district lies between 22° 41' 11" to 24° 41' 47" North latitude and 68° 9' 46" to 71° 54' 47" east longitude. The district had nine talukas: Abdasa, Anjar, Bhachau, Bhuj, Lakhpat, Mandvi, Mundra, Nakhtrana and Rapar (Fig. 1), but

Table 1. Area (000 ha) under forest, unculturable wasteland and culturable wasteland in Gujarat

District	Total geo-graphical area	Forest		Unculturable Wasteland		Culturable Wasteland	
		Area	Per cent	Area	Per cent	Area	Per cent
Ahmedabad	8707	115	1.3	718	8.3	228	2.6
Amreli	6760	380	5.6	184	2.7	101	1.5
Bansaskantha	12703	1500	11.8	343	2.7	251	2.0
Bharuch	9038	1450	16.0	213	2.4	394	4.4
Bhavnagar	11155	315	2.8	1009	9.0	310	2.8
Dangs	1764	1688	95.7	-	0.0	-	0.0
Gandhinagar	653	-	0.0	2	0.3	15	2.3
Jamnagar	14125	424	3.0	1572	11.1	329	2.3
Junagardh	10607	1993	18.8	310	2.9	122	1.2
Kheda	7194	98	1.4	326	4.5	28	0.4
Kachchh	45652	2868	6.3	17074	37.4	16805	36.8
Mehsana	9027	178	2.0	132	1.5	140	1.6
Panchmahals	8850	2244	25.4	378	4.3	123	1.4
Rajkot	11203	359	3.2	1087	9.7	128	1.2
Sabarkantha	7390	1277	17.3	358	4.8	147	1.9
Surat	7762	1420	18.3	608	7.8	224	2.9
Surendranagar	10489	496	4.7	1296	12.4	134	1.3
Vadodara	7794	818	10.5	279	3.6	91	1.2
Valsad	5244	1249	23.8	158	3.0	199	3.9
Gujarat state	196117	18872	9.6	26050	13.3	19769	10.1

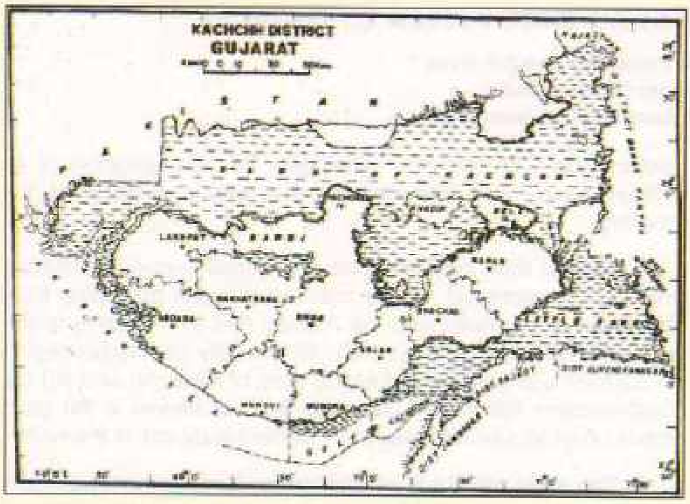

Fig.1. Kachchh district location map

recently one more taluka of Ghandhidham has been carved out from talukas of Anjar and Bhuj. The soils in the district are shallow, sandy with high permeability and low water retentvity. These are grouped as a) fine textured b) moderately fine textured c) medium textured d) coarse to moderately textured e) coarse textured and f) miscellaneous soils. The pH of soils ranges between 8-9 and Ec between 220-24159 S cm^{-1} at 1:2 (Singh and Kolarkar, 1999). According to Kanzaria (1994) soils are low in fertility status, have poor biological activity and are highly saline. Only 21 per cent soils of the land area are fit for agriculture. Rao *et al.* (1999) noted that the climate of the district has three distinct seasons, winter (Nov. - Feb.), summer (March June) and monsoon (Jul. - Oct.). Other mean climatic characteristics of the district are presented in Table 2.

Table 2. Climatic characteristics of Kachchh

Parameter	Range	
	Maximum	Minimum
Temperature (°C)	39-45	1-8
Relative humidity (%)	60-80	21-59
Wind speed (kmh^{-1})	19-37	5-14
Evapotranspiration (mm)	251-266	75-92
Av. annual rainfall (mm)	326	
Av. rainy days	13	

The state grows multifarious crops as it experiences wide variations in its soil and agroclimatic condition. The agriculture at the state level is predominantly under oilseeds (groundnut, sesame, mustard, castor, etc.) followed by cereals (paddy, wheat, bajra, sorghum, maize, etc.), fibre, pulses, sugarcane, spices and condiments, etc. But nowhere mehndi (henna) is cultivated as in Rajasthan. However, mehndi is found on farm boundaries as live hedge, or as ornamental hedge in public places and schools in particular since it is not browsed by animals and can easily be grown on all types of soils ranging from sandy soils, stony soils to wastelands that are not suitable for the economical cultivation of any other crop.

Trials at Different Locations

To explore the possibility of mehndi cultivation as a cash crop in Gujarat, ten promising provenances were planted on onset of monsoon in 2002 at five places in different agroclimatic zones viz. Danti-Ubharat (Zone-I), Vadodara (Zone-III), Sardarkrushinagar (Zone-IV), Radhanpur (Zone-IV) and Kothara (Zone-V). The soils of Danti-Ubharat are coastal salt affected clay loam with frequent ingress of seawater. The soils of Vadodara are deep clay loam with good water holding capacity covered under Mahi command suitable for all the cash crops of the region. The soils of Sardarkrushinagar (Dantiwada) are marginal loamy sand with poor water holding capacity. The soils of Radhanpur are desert sand and saline alkaline. The Kothara (Kachchh) soils are coastal, salt affected, shallow and sandy loam with poor fertility. The provenances were evaluated under rainfed conditions and dry foliage yield (kg ha^{-1}) was recorded during second year of plantation (2003-04).

At Danti-Ubharat, none of the provenance could survive because of the high coastal salinity and frequent sea tides. In Zone-III i.e. at Vadodara provenance from Bikaner yielded highest dry foliage yield of 3585 kg ha^{-1} followed by Dhandhuka and Pali. Under arid rainfed condition at Sardarkrushinagar and Radhanpur provenances from Dhandhuka and Sardarkrushinagar performed superior under agroclimatic conditions of Zone IV (Table 3). The provenances from Panchotia (Rajasthan) recorded the highest dry foliage yield of 4560 kg ha^{-1} under irrigated condition at Sardarkrushinagar.

At Kothara located in Kachchh (north-west Gujarat) dominated by various stresses viz. scanty and low rainfall, salinity and harsh climate, provenance from Panchotia followed by Sojat and Kothara recorded the highest dry foliage yield of 1410 kg ha^{-1}, which is quite high under adverse conditions where cultivation of other arable crops is not economical (Table 3). The research results have indicated possibility of commercial cultivation of mehndi under rainfed conditions where cultivation of any other crop is not remunerative.

Table 3. Dry foliage yield ($kgha^{-1}$) of provenances at various locations during 2003-04

Sl. No.	Provenances	Dry foliage yield (kg/ha)				Lawsone content (%)
		S.K. Nagar	Vadodara	Radhanpur	Kothara	at S.K. Nagar
1.	Kothara	2426	2110	74	1325	2.53
2.	S.K. Nagar	1466	2450	334	715	2.35
3.	Kota	2226	2385	65	820	2.54
4.	Dhandhuka	3206	3270	55	1025	2.38
5.	Pali	1673	3000	153	810	2.61
6.	Bikaner	1613	3585	120	840	2.42
7.	Sojat	1580	2625	122	1340	2.48
8.	Jodhpur	2160	2890	73	1160	2.40
9.	Panchotiya	2893	2115	68	1410	2.47
10.	Anand	2226	2500	148	1215	2.41
	Mean	2147	2693	121	1066	2.46

The commercial cultivation of mehandi has also been demonstrated by Central Arid Zone Research Institute at RRS Kukuma, Bhuj (Vyas, 2001) (Fig. 2). Vyas (2005) has shown that cultivation of this crop in Kachchh region is economically viable (Table 4). It has also been demonstrated that crop has adaptability for alternate land use systems as yield is not much affected under shade (Vyas, 2004).

Table 4. Economic returns (Rs./ha) from henna

Year	Rainfall (mm)	Expenditure	Gross income	Net returns
Bad	52.9	2000	8331	6331
Normal	303.5	5000	18,335	13,335

Scope of Henna Cultivation

Henna has been identified as a cash crop for arid and semiarid wastelands because its produce is in high demand in export market. In India, it is largely grown as hedge plant throughout country, large-scale commercial cultivation is confined only to the state of Rajasthan and to some extent in the state of Gujarat.

In Gujarat, it is grown in the Bardoli and Madhi talukas of Surat district. However, there is no proper documentation of information on area, production and productivity as the crop is of minor importance in these talukas. In Kachchh district henna is generally grown as hedge or for ornamental purpose in gardens but there is no commercial cultivation.

The state has 96 lakh ha land under cultivation. Around 10 per cent of the land of the state is categorised as cultivable waste. Kachchh alone has got about 37 per cent of the land under this category. The encouraging performance of different provenances of mehndi at Kothara (Kachchh) and trials at RRS, Kukuma (Bhuj) indicate the possibility of cultivating mehndi on marginal and salt affected soils also. As a large area in different agroclimatic zones of the state is salt affected (Table 5) where arable crops are not remunerative, mehndi cultivation is feasible with appreciable returns.

Table 5. Area (lakh ha) under salinity in different agroclimatic zones of Gujarat

Agroclimatic zones	Area (lakh ha)	Area under salinity (lakh ha)	percentage
South Gujarat (high rainfall)	10.00	1.11	11.00
South Gujarat	11.00	1.41	10.36
Middle Gujarat	24.00	0.62	2.58
North Gujarat	23.00	0.10	0.43
Northwest	35.00	28.15	80.43
North Saurastra	35.20	6.47	18.41
South Saurastra	17.00	9.34	54.94
Bhal and coastal area	12.00	11.21	93.42
Total	167.20	58.41	34.93

In arid and semi-arid region of Gujarat where rainfall is low as well as erratic, soils are salt affected, sandy to sandy loam with poor water holding capacity, the underground water is brackish and not fit for irrigation and hampering economical cultivation of arable crops, the cultivation of mehndi in such area or as a biofence on farm borders in normal fertile soils has a bright prospective as a rainfed plantation crop.

Fig. 2. An overview of henna cultivation at CAZRI, RRS, Bhuj

A few farmers have come forward for cultivation of henna on small scale in kachchh region. Since, crop can be cultivated in diverse soil types from sandy to stony wastelands unfit for commercial crops, its cultivation can be expanded on these areas on individual or co-operative basis by NGO's or village panchayats. The cultivation of mehndi in such problematic areas will not only improve economic condition of the farmers but will also improve/maintain soil fertility by controlling soil erosion through wind and water.

References

Anonymous 1995. *Wealth of India*. CSIR, New Delhi.

Kanzaria, M.V. 1994. Soils of Kchchh an ecological Prospective. A dossier on Kachchh (Soil/ Geology). Proceeding of seminar. Jan. 20 21. VRTI. Mandvi.

Patel, N.K. and P.H., Bhatt. 2000. Agriculture in arid Zones of Gujarat. In *Priorities of Research for Development of Arid Regions*. (eds. Verma, S.K., Nahar, N.M., Bhansali, R.R., Jindal, S.K. and Satyavir) Scientific Publishers India, Jodhpur. pp. 49 60.

Rao, A.S., R.S., Singh and Y.S., Ramakrishna. 1999. Climate: *In Integrated Natural and Human Resource Appraisal for Sustainable Development of Kachchh district*. (eds. Singh, S. and Kar) CAZRI, Jodhpur. pp. 5-14.

Singh, N. and A.S., Kolarkar. 1999. Soil and Land Use capability. In *Integrated Natural and Human Resource Appraisal for Sustainable Development of Kachchh district*. (eds. Singh, S. and Kar, A.) CAZRI, Jodhpur. pp. 24- 49.

Vyas, S.P. 2001. HENNA : a cash crop for arid Gujarat. *Den News*, CAZRI, Jodhpur, 5: 2-3.

Vyas, S.P. 2004. Influence of light intensity on growth, yield and lawsone content of Henna (*Lawsonia inermis* L.) *Indian, J. Plant Physiol*. 9: 275-277

Vyas, S.P. 2005. The performance of *Lawsonia inermis* L. in arid Gujarat. *Indian J. Soil Conservation* (in press)

Scope of Henna In Semi-arid Tropics of Southern India

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Henna, *Lawsonia inermis* is an important dye-yielding crop. The preliminary studies conducted at CRIDA revealed that henna is a promising perennial bush. Its cultivation under dry lands is profitable and sustainable (Korwar and Pratibha, 1998).

Henna is grown commercially in south but not much was exported. The production in south cannot meet the requirements of the local market also. Hence the crop has tremendous scope for further expansion in marginal drylands of semi-arid regions. The main reason for this is the crop once established does not require any special attention or much recurring expenditure. Studies on standardization of agrotechniques for henna to obtain higher yield and quality were initiated at CRIDA from 1994. The results of the studies are briefed here.

Diversity in Henna Accessions

The yellow flowered henna is mostly cultivated in arid and semi-arid regions. There are no released varieties in India. However morphological variation and difference in yield and quality exists in different accessions. Hence considerable scope exists for germplasm selection for high yield and lawsone content. Research studies were initiated to identify superior lines from different accessions collected from Rajasthan and Andhra Pradesh. The studies indicated that the collections from Pali recorded higher yields when compared to other accessions where as accessions from Sojat recorded higher lawsone content (Table 1).

Soil and Climate

The henna is adaptable to wide range of climatic conditions. It is tolerant to drought condition. The correlation coefficients were worked out between rainfall, temperature vs. yield and quality to study the influence of environment on yield and quality. It was observed that the quality of henna was significantly negatively correlated with rainfall and minimum temperature, where as it was positively correlated with maximum temperatures (Table 2). However it was also observed that only some accessions had significant correlation with environmental factors, while other accessions do not have any significant correlation with environment. Hence selection of accessions, which do not respond much to environment, may be given priority.

Deep fine sandy or medium textured well-drained soil is considered best for henna cultivation. The soils of the semi-arid regions are alfisols with a pH of 7.5. The available nitrogen, phosphorous and potassium are low. The water holding capacity of the soils is also low. The studies indicated that henna could successfully be cultivated in saline soil. Fourteen per cent increase in yield in saline soils was observed when compared to normal soil. The quality of leaf was also better in saline soils. Application of *Glyricidia* in saline soils recorded higher yield and quality over chemical fertilisers and no fertilizer application (Fig 1)

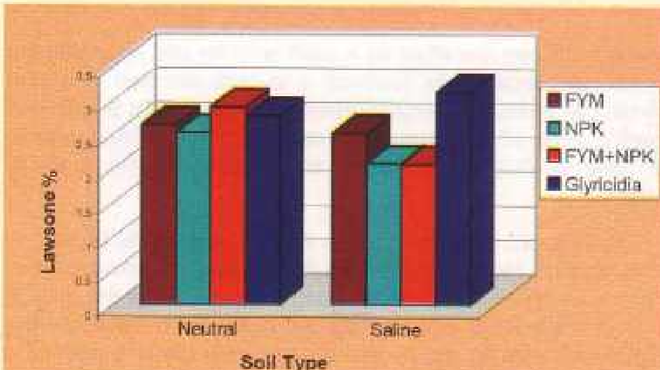

Fig.1. Influence of Different soil types on Quality of Henna

Nursery Practices

Henna is propagated by both cuttings and seedlings. However seedlings are preferred over cuttings as the survival of seedlings (88%) is better when compared to cuttings (67%). The better survival of seedlings is due to better root growth than cuttings. Research results of the experiments at CRIDA revealed that cuttings recorded higher yield where as seedlings had better quality than cuttings. The higher yield in cuttings is due to more branching. Early flowering was observed in cuttings than seedlings. Due to flowering the photosynthates are diverted to flowers and seed formation. Hence the photosynthates available for synthesis of secondary metabolites are reduced which in turn reduces the lawsone content.

Henna seeds have a hard seed coat and take lot of time to germinate and the germination percentage was poor. Hence different seed treatments like sprouting (seeds were soaked in water for overnight and the seeds are spread on moist gunny bag and covered with another bag. The gunny bag should be watered in the morning and evening after 3 days the seeds can be sown in

Table 1. Leaf yield and quality of different accessions (Average of 4 years)

Accession	December			June		
	Yield g/pl	Lawsone %	Leaf: Stem ratio (%)	Yield g/pl	Lawsone %	Leaf: stem ratio (%)
PRSN	65.82	2.08	14.55	9.83	2.32	21.24
PRSO	18.97	2.21	10.91	3.91	2.40	19.77
JRF	37.70	1.75	15.34	3.87	2.20	14.43
Sojat 1	15.41	2.14	9.68	2.20	2.79	16.57
Local 1	27.70	1.97	13.42	2.32	2.85	16.00
Sojat 2	14.01	1.98	12.91	1.29	3.15	17.09
Local 2	11.70	1.72	12.50	1.37	4.20	18.38
Sojat3	18.04	3.31	14.44	1.96	3.06	18.90

Table 2: Correlation coefficients between different variables

Variable	Yield	Lawsone	L-S Ratio
Rainfall	0.66	-0.698	-0.590
Maximum Temperature	-0.58	0.594	0.734
Minimum Temperature	0.55	-0.498	-0.537
L-S Ratio	-0.25	0.354	-

raised nursery bed), soaking for 24 hrs, soaking for 7-10 days with changing water and acid scarification were tried, but the germination percentage was 70-80 per cent in sprouting treatment. The seedlings are slow in growth for initial 30 days. Hence three months old seedlings are transplanted for better survival. The seeds are sown in a raised nursery bed during the month of March. The nursery is often infested by cuscuta. The seeds of henna resemble the cuscuta seeds hence it is difficult to eradicate them from seed lot, so care should be taken to collect seeds from a clean plantation.

When cuttings are to be transplanted, the cuttings should be kept in the poly bags and after rooting, 3-4 months old cuttings are transplanted into main fields. Trials were conducted at CRIDA to study the influence of temperature, humidity and hormones on the rooting of cuttings. The cuttings were kept in both open and indigenous mist chambers. The mist chamber was used to raise the temperature and humidity. It was observed that, there was 70 per cent rooting in indigenous mist chamber where as it was only 15 per cent outside. Treatment of cuttings with 200 ppm IBA recorded significantly higher rooting over control and higher concentrations. The rooting percentage and root dry weight was better in mist chamber when compared to outside even without hormone treatment this could be due to higher temperature and humidity in the mist chamber. Transplanting of seedlings with onset of rains in second fortnight of June recorded significantly higher survival percentage.

In agroforestry system seedlings were transplanted at 2mx1m spacing. When seedlings are planted at 2mx1m spacing, microsite improvement increased the survival percentage and yields over no microsite improvement. There was 29, 44 and 16 per cent increase in yields with microsite improvement over no microsite improvement in 1996, 1997, and 1998 respectively. The positive influence of microsite improvement could be attributed to better moisture retention and higher nutrient content in these plots, which was mainly due to FYM and tank silt application. The bulk density decreases and porosity increases due to microsite improvement, this decrease in bulk density helps in better root growth and increases the yield (Pratibha and Korwar, 2004). The quality of leaf was better in microsite improvement especially in post-rainy season.

Nutrition

Henna removes a large quantity of nutrients from soil. A yield of 1000 kg ha^{-1} of dry leaves removes 180-190, 100-150, 10-30 kg ha^{-1} of nitrogen, potash and phosphates. Hence timely and adequate application of chemical fertilizers is important to achieve better yield and quality. N plays a vital role in promoting vigorous growth, as this crop is cultivated for dry leaf. Application of 60 kg ha^{-1} N has recorded higher yields and is on par with 90 kg ha^{-1} in arid regions (Rao *et al.*, 2003). The input levels vary enormously in different locations depending upon soil type.

Nutrient and environment interactions seem to play a significant role in the over all response of the crop to applied nutrients. The trials revealed that application of fertilizers recorded higher yields and quality over no fertilizer application. In another trial preliminary results indicated that combination of FYM+NPK recorded higher yields over organics or inorganic alone.

Dry leaf yield and quality of leaf were influenced by nitrogen and phosphorus application. Application of 80 kg N ha^{-1} and 30 kg P ha^{-1} respectively recorded higher yields. Where as higher lawsone content was observed in no nitrogen and 30 kg ha^{-1} of P applications.

Irrigation

Henna is usually cultivated as rainfed crop. Wherever irrigation facilities are available the crop can be irrigated after December (post-rainy season) to increase the yield. However frequent irrigations are believed to decrease the leaf quality by lowering the dye content.

Harvesting and Post-harvesting

Henna is harvested usually twice a year (May and December) in the semi-arid regions. The crop establishes well and starts economic yield after second year. Harvesting should be done on a clear sunny day. The crop is harvested after it is fully mature. If the harvesting is done after the crop is fully mature, the leaf starts dropping. The farmers usually say that their yields are reduced due to leaf drop. After cutting, the leaf is allowed to dry while still attached to the stem and leaving the crop in the field may do this. The rainy season harvest yields are more when compared to post-rainy season.

The crop after harvesting should be dried properly, otherwise the leaves loose colour and there is fast deterioration of quality on storage. Retention of a desirable attractive green colour is assisted by drying in the shade but this is impractical when there is large area and in the absence of suitable facilities. For maintaining post-harvest quality use of simple, inexpensive driers in humid climates is essential. Studies revealed that drying at optimum temperature of 50° C maintains the colour and higher dye content. The deterioration in quality on storage also was fast in sun and shade drying when compared to oven drying (Fig. 2). Most of the dried leaf can be simply detached by beating the stem on the ground. This should be done on a clean surface to avoid soil contamination and the inclusion of extraneous matter. Packing in clean bags should be made as soon as possible after the harvest, to avoid deterioration during storage.

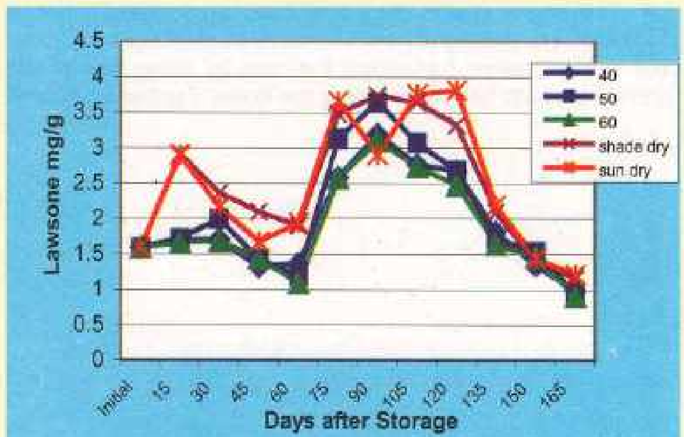

Fig. 2. Influence of Different Drying Temperatures on Lawsone

Quality

The major pigment in henna leaf responsible for orange colour is lawsone. The lawsone content of leaves varied from 2-2.5%. The lawsone content depends on various factors like environment, agrotechniques. A simple estimation method of lawsone content was developed at CRIDA (Pratibha and Korwar, 1999). Further it was observed that use of tap water around pH of 7-7.5 or a neutral buffer for extraction of colour helps in obtaining good results when compared to distilled water. Additional quality tests may be made for adulterants and microbial load.

Economics

About 40 per cent of the total leaf production of henna is exported to France, U.K, Syria, Algeria, Jordan, USA etc. The average yield of henna under semi-arid region was 2-2.5 t/ha, the average cost of cultivation will be Rs. 15,000 for establishment and recurring costs every year will be on weeding and harvesting. It will be around Rs. 4000 to Rs. 5000 ha^{-1}. Trials in CRIDA revealed that, the equivalent yields were in the order Henna > Bixa > Indigo > Sunflower > Sorghum. Henna recorded higher economic returns over arable crops like, sunflower, sorghum and other dye crops like indigo and bixa (Fig. 3).

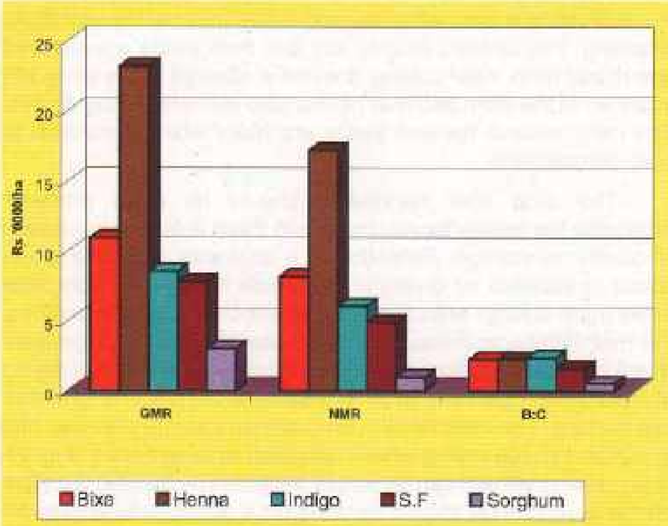

Fig.3. Econmics of different crops

The labour cost is the major cost component for henna cultivation. Harvesting of henna involves lot of labour and labour cost is high, hence harvesting the crop by using any simple machines would help in reducing the costs. Further compared with other crops henna has the capacity to give assured income under unfavorable conditions when compared to other crops.

There is considerable scope of growing henna for the economic development of the semi-arid regions and waste lands. It can also be cultivated on marginal lands and on lands, which are unsuitable for cultivation of other arable crops.

References

Korwar G.R., and G.Pratibha. 2004. Diversity in henna accessions. *Proceedings Research and developments in Production, protection, Quality, Processing and marketing of Medicinal & Aromatic Plants.*27-29 Feb 2004, CCS Haryana Agricultural university, Hissar India pp 8-10

Korwar G.R., and G.Pratibha. 1998. Alternative land use systems for marginal lands. Extended summaries, *First International Agronomy Congress*. 23-27 November 1998,ISA, New Delhi pp37-38.

Pratibha G., and G.R.Korwar. 1999. Estimation of lawsone in henna (*Lawsonia inermis*). *Journal of medicinal and Aromatic plant Sciences* 21: 658-660

Pratibha G., and G.R.Korwar. 2002. Crop diversification through medicinal, aromatic and dye yielding plants for sustainability in semi-arid regions *Proceedings of First national meet on Medicinal & Aromatic Plants*. eds Mathur A.K., S Dwivedi, DD Patra, GD Bagchi, NS Sangwan, A Sharma and SPS Khanuja. CIMAP, Lucknow PP: 129-132.

Pratibha G., and GR Korwar. 2004. Influence of dates of planting, microsite improvement and planting materials on the yield and quality of *Lawsonia inermis*. *Journal of Medicinal and Aromatic Plant Sciences* (In press)

Rao SS PK Roy and P L Regar. 2003. Effect of crop geometry and nitrogen on henna leaf production in arid fringes. *Indian Journal of Agricultural Sciences*. 73 (5): 283-285

Agri-history, Uses, Ecology and Distribution of Henna (*Lawsonia inermis* L. syn. *alba* Lam.)

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Henna, today found all over the world, is a native of the Old World tropics and is believed to have originated in North Africa (Egypt's arid area or perhaps Ethiopia). Egyptian people have been using henna since very early days of civilisation for medicinal and cosmetic purposes. In fact some of the oldest mummies found, including a woman, had traces of henna in hair weave. Pyramid wall etchings, specifically in the tomb of Teta/Teti in Saqqara (c.2291 BCE) which mentions "henu" appears to be the first true mentioning of Henna. The writings of ancient Greeks and Romans show how henna was used and exported from Egypt (Miczack, 2001).

Agri-history

Henna is abundantly cultivated in Egypt in gardens for its strong smelling of flowers and farm crop for its leaves since 2000 BC (Gode, 1999). Henna appears to have reached India around the Mauryan dynasty, for use by the rich and royal as hair colour and perfume. Its commercial cultivation started much later. Prior to introduction of henna, Indians used Laksa tree dye to stain their hands. There were many other botanicals in use like alta, turmeric, kumkum, myrtle (*Myrtus communis*), alkanet (ratanjot), indigo, madder, etc. Though henna is widely distributed in African & Asian continent, but systematic cultivation of henna initiated in Egypt during mohmedans era around 6-7 AD. Henna possibly migrated to Sind from Egypt via Iran in cultivated form around 712 AD. Later, Md. Gauri defeated Prithvi Raj Chouhan in 1192 AD and his commandent belonging to slave dynasty appointed as sultanate of Delhi established henna gardens around Faridabad, Gurgaon around 1200 AD, which was referred in Aine Akbari (Gode, 1999). These Turkish rulers were fond of dyeing their hair in reddish brown colour as it is most common ritual in Islamic culture. The "Night of Henna" and patterned henna designs on women came with the Mogul invasions and slowly caught on by the 16th century. It was in cultivation at Faridabad and surrounding up to 1980, but hike in land prices due to urbanisation wiped it out of cultivation. Even today there are about twenty small or big factories in Faridabad dealing with henna processing and trade. In the mean time, henna cultivation has started taking shape about 100 years back in Rajasthan around Bhawani Mandi, Kota and Sojat but actual expansion occurred after independence. Sojat and surrounding areas were traditionally under cotton. Area under henna in Sojat region rose from 157 ha in 1953 to 35000 ha in 2003 (Anonymous, 2003).

Due to the fact that henna has been in existence and used for thousands of years, there are plethora of names associated with it. The ancient Arabic name Henna or Hinna is by far the most used and well known of all the names. Hinna, meaning to dye red, appears to have originated in Arabic speaking Persia. In India the henna plant is separated into the two main colours of flowers produced. Madayantika for the white to yellowish flowers and Kuranaka for the red, pink and deep purple colour of the flowers. Mehndi is possibly the shorter version of the Sanskrit word (Mendi)ka, meaning myrtle that encompasses number of plants. Originally henna when introduced to India was thought to be one type of myrtle and thus was known as Hina Mehndi, but then Hina seems to have been dropped (Miczack, 2001).

Economic Uses

Henna leaves containing lawsone are used to colour skin, nails, body and hairs as natural herbal dye all over the world and is also getting popular for tattooing. Henna is used as drug for medical as well as veterinary purposes (Ghosh, 1999; Kumar and Gopal, 1999). Plant has also ability to control various plant diseases caused by bacteria, fungal and nematodes (Korayem. and Osman, 1992; Singh and Singh, 1997; Satish *et al.*, 1999). The henna root is used in jaundice and enlargement of the spleen. The leaves are externally applied for headache (mild analgesic), rubbed over the soles of the feet in the burning of the feet. The decoction of the leaves is used as an astringent and gargle in sore throat. It is also a remedy for spermatorrhoea. The essential oil is used to keep the body cool. The leaves are used as a prophylactic against skin diseases, jaundice, leprosy and smallpox. They are used externally in the form of a paste or decoction against boils, burns, bruises and skin inflammations. Alcoholic extracts of *Lawsonia* leaves show mild antibacterial activity against *Micrococcus pyogenes* var. aureus and *Escherichia coli* (Kirtikar and Basu, 1981). It was extensively used as a dye in silk and wool industry. Use of henna during beatification preparation of the mummies and other diverse uses have been discussed by Miczack (2001).

Its flower are used to make scent. Scent manufacturing is very common in India at Kannanj (U.P.) and Ujjain (M.P.). Hina Attar is traditionally produced by soaking crushed flowers in oil for many days. Its pungent nature is because of beta-ionone that provides both an antifungal and bactericide properties. Egyptians used henna more for its medicinal uses, eventhough today we see it more as a cosmetic or for its perfume use.

Botany

Lawsonia inermis L. of family Lythraceae is a tall shrub to small tree, 2-6 m high. It is glabrous, multibranched with spine tipped branchlets which are green when young but turn red with age. Leaves are opposite, entire, glabrous, sub sessile, elliptical, broadly lanceolate (1.5-5.0cm x 0.50-2.0cm), acuminate having depressed veins on dorsal surface. It has whitish, small, fragrant flowers in large terminal cymes. Each flower has 4 sepals, 2 mm calyx tube with 3 mm spread lobes. Petals are obovate, white or red and stamens inserted in pairs on the rim of calyx tube. Ovary is 4 celled, style up to 5 mm long and erect. Fruits are small, brownish capsules, 4-8 mm in diameter, many seeded, opening irregularly into 4 splits. Style is persistent, seeds 3 mm across, angular with thick seed coat.

Geographical Distribution

It occurs naturally in North Africa mainly in countries of Algeria, Cyprus, Egypt, Eritrea, Ethiopia, Indonesia, Iran, Iraq, Jordan, Kenya, Kuwait, Lebanon, Libya, Malaysia, Morocco, Oman, Philippines, Qater, Saudi Arabia, Syrian Arab Republic, Tanzania, Tunisia, Turkey, Sahara and Yemen. In many of these countries, it naturally occurs along water courses and semi-arid region where it can withstand drought and dryness. It has been introduced into countries like Australia, Benin, Burkina Faso, Cameroon, Central Africa, Chad, Congo, China, Gabon, Gambia, Ghana, Guinea, India, Liberia, Mali, Mauritania, Niger, Nigeria, Pakistan, Senegal, Sierra Leone, Spain, Sudan, Togo, and Zanzibar.

Ecological Requirements

It prefers well drained sandy to sandy clay loam soils in younger and older alluvial plains. It's temperature limits are 19 to 27°C. Soil pH could be 4.3 to 8.0 with gravels and pebbles in it. Even poor, stony and sandy soil can also become its abode. It is believed that dry, hot iron bearing soils produce henna with high lawsone content. Moist, fertile soils produce henna with lower lawsone levels. However, it needs field level confirmation.

In India most of henna is cultivated in Pali district of Rajasthan. The Pali district, lies between 24°45'-26°29'N and 72°47'-74° 18'E at 212 m above mean sea level, receives rainfall within a range of 360 mm to 550 mm per annum. The soils of Pali district are sandy loam with pH 8.1, EC 0.16 dSm^{-1}, organic carbon 0.37%, low available N (213 kg ha^{-1}), available phosphorus 11.0 kg ha^{-1} and exchangeable K 250 kg ha^{-1}. The soil has 45% sand 36% silt, 19% clay, 1.36-1.49 g cm^{-3} bulk density, 18.5% (w/w) field capacity and 8.6% (w/w) permanent wilting point (-15 bar tension). The depth of soil varies from 20 cm to 60 cm in the area. The subsurface layers is calcareous at many places in Sojat and surrounding areas. The calcareous layer rich in calcium helps to retain water in subsoil and Ca found in natural form provides strong base to improve the quality of henna leaves. Sojat and Marwar occupies 90% of the total area under mehndi in India. It occupied around 28% and 22% of total culturable land at Sojat and Marwar, respectively.

Henna regenerates easily from stem cuttings. Seeds before sowing in nursery are kept dipped in water for 3-7 days, with daily change of water and are then kept in small heaps, moist and warm for a few days. This requirement of its germination therefore, needs a thorough understanding of its germination ecology. Water travel seems as the most important method of transportation. Miczak (2001) has opined that henna was carried to various areas via water, such as the Nile and even the sea, as salt water does not effect the germination capabilities.

Estimation of Area under Henna

It is widely believed that some 35-40 thousand hectares of area is under its cultivation. Mehndi cultivation is spreading fast in the adjoining areas of Sojat, in Nagaur and Jodhpur district. This not only requires extension services in the new areas for better yield, but it also warrants an enhanced logistics for its procurement, processing, packaging and quality control besides collecting revenue and cess for the treasury. Estimating area under its cultivation every year is therefore, a foremost requirement for a host of planning agencies. This has so far been done by the conventional field based patwari level assessments, even though techniques of remote sensing have marched ahead. Possibility of using this modern tool for estimating area under henna has been examined here.

Vegetation under sun can either absorb, reflect or transmit the radiations and this can be best expressed as follows.

$$\lambda I = \lambda R + \lambda A + \lambda T$$

Where I = incident radiation
R = reflected radiation
A = absorbed radiation
T = transmitted radiation
λ = wavelength

Green leaves have poor reflectance in blue and red spectral region of the visible spectrum. It has high reflectance, high transmittance and very low absorption in the near Infra-red region (0.8 to 1.2 micron) in which 45-50 per cent of incident light is reflected. This reflected energy is captured by a sensor in a satellite orbiting around earth and sent back to earth stations where it is retrieved as images. These picture images are called pixels the size of which varies as per resolution. This reflectance can also be altered by status of soil moisture roughness, organic matter, clay and sand proportions. Vegetation detection basically involves differentiating the reflective properties of vegetation from its soil background. In the next step, a particular species in larger spreads could be mapped by its specific spectral response behavior compared to other species. An exercise on spectral responses of mehndi was carried out to assess its potential for large scale mapping.

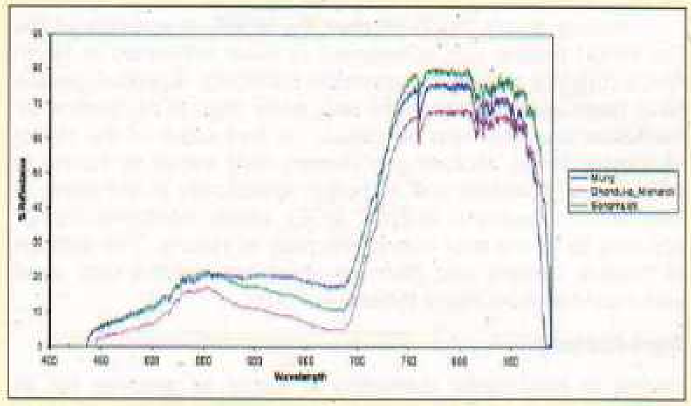

Fig. 1. Spectral responses of henna and other crops in Jodhpur

The spectral reflectance of Henna, Sonamukhi (*Cassia angustifolia*) and Mung bean were recorded between 11 AM to 1PM on 19.9.04 at CAZRI Campus. Each object was referenced with respect to white reflective plate of 'spectralon' using ocean optics spectrometer A sample plot of reflectance in 450-850 nm range (Fig. 1) revealed that these curves are most separable in 600-700 nm range and 750-850 nm range which correspond to red and mid infrared range. It may therefore be possible to detect henna plantation using a suitable vegetation index on remote sensing data. Area under henna can be confirmed using maximum likelihood classifier approach in both supervised and un supervised classification approach. In depth studies for at least two growing seasons are required to arrive at tangible conclusions.

Reference

Anonymous. 2003. *Agricultural Statistics of Rajasthan*. 2001-2002. Directorate of Statistics, Yojana Bhawan, Jaipur, Rajasthan.

Ghosh, A. 1999. Herbal veterinary medicine from the tribal areas of Bankura district, West Bengal. *Journal of Economic and Taxonomic Botany*, 23:557-560.

Gode, P.K. 1999. History of henna (2000 BC to 1850 AD). *Asian Agric. History*. 3:235-244.

Kirtikar, K.R. and B.D. Basu 1981. Lythraceae. In: K.R. Kirtikar and B.D. Basu (Eds.). *Indian Medicinal Plants*. Vol. II, International Book Distributors, Rajpur Road, Dehradun, India, p.1076-1080.

Korayem, A. M. and H. A. Osman, 1992. Nematicidal potential of the henna plant *Lawsonia inermis* against the root knot nematode *Meloidogyne incognita*. Anzeiger Fuer Schaedlingskunde Pflanzenschutz Umweltschutz, 65:14-16.

Kumar, S. and K. Gopal, 1999. Screening of plant species for inhibition of bacterial population of raw water. *Journal of Environmental Science and Health Part A Toxic Hazardous Substances and Environmental Engineering*, 34:975-987

Miczak Marie Anakee. 2001 Henna's Secret History The history, mystery & folklore of henna. Publishers Writers Club Press, San Jose, New York Lincoln, Shanghai p 326

Satish, S. and K. A. Raveesha, 1999. Antibacterial activity of plant extracts on phytopathogenic *Xanthomonas campestris* pathovars. *Letters in Applied Microbiology*, 28: 145-147.

Singh, C. J. and B. G. Singh, 1997. Antifungal activity of some plant extracts against dermatophytes and related keratinophilic fungi. *Advances in Plant Sciences*, 10: 249-251

Natural Variability, Propagation, Phenology and Reproductive Biology of Henna

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Over a century ago, Darwin (1859) noted the universality of natural variation and this formed the inspiration for his great work on the evolution of species by natural selection. Genetic diversity found in tree and shrub species is a part of nature's strategy for defence and survival against all types of risks encountered in their long life span (Heybrock, 1978). The use of diversity of wild species for genetic gain is the basis of improvement work. Henna is not found in natural habitat in India and is under cultivation in few pockets. The pockets are also shrinking, as the earlier locations in Punjab and Faridabad are no more growing this species due to changes in land use. In 1955 out of the estimated henna production of 65,000-70,000 md in the country, Faridabad in district Gurgaon and Bardoli and Madhi in Dist Surat contributed about 47 per cent and 41 per cent. The contribution of Rajasthan was less than 5 per cent (Anon. 1962). At present, most of henna is cultivated in Sojat area of Pali district of Rajasthan. As the plantations are established using seedlings raised from seed collected randomly, the plantations represent the segregating material and/or mixture of various genotypes. The results presented in this article are based on our survey of farmers' field in Sojat and surrounding areas.

Natural Variability

The mean, range, standard deviation and coefficient of variation of twelve characters recorded on 84 plants studied during 2000 and 2001 in natural stands of henna are given in Table 1. Plant height ranged from 60 cm to 180 cm with a mean of 99.10 cm. Canopy diameter ranged from 35 to 205 cm with a mean of 96.26 cm. Lawsone per cent ranged from 0.55 to 2.00 with a mean value of 1.14. Weight of 10 fruits had a range of 0.20 g to 0.71 g with a mean of 0.48 g. Number of seeds per fruit had a range of 18 to 63 with a mean value of 36.33. Weight of 100 seeds had a range of 0.05 g to 0.15 g with a mean of 0.08 g. The coefficient of variation was 25 to 38 per cent in different traits. Maximum coefficient of variation was observed for lawsone (38.07%).

Besides the above-mentioned characters, data were also recorded on approximate age of the crop, type of soil, type of area (rocky/plain), irrigated/non-irrigated, associated crops, diseased/healthy, etc. There is no standard method to estimate the age of henna, so information from the owners of field was relied upon. The approximate age ranged between 15 to 25 years. Type of soil in almost every field was sandy, though in a few fields it was gravely sand. In most of the fields, crop was rainfed, and had pale-white flowers. However, many hedge plants at CAZRI had reddish flowers (Fig. 1)

The analysis of data of 84 shrubs revealed that most of the relationships were non-significant. Positive and significant correlations were observed in combinations of height with canopy diameter and length of leaves with width of leaves; 100 fresh leaf weight with 100 dry leaf weight; length of fruits with width of fruits and weight of 10 fruits; width of fruits with weight of 10 fruits; and weight of 10 fruits with number of seeds per fruit. Lawsone per cent was negatively associated with 100-seed weight. (Table 2).

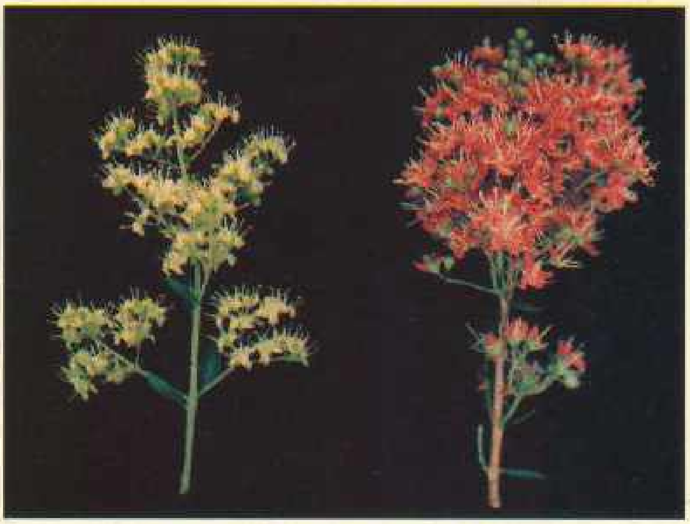

Fig. 1. White and red flowers of henna

Genetic divergence

Assessment of genetic divergence among 84 accessions of henna was carried out, using non-hierarchical Euclidean cluster analysis, and the results are presented in Table 3. The inter-

Table 1. Mean, range, SD and CV of *L. inermis* plants surveyed during 2000 and 2001 in Sojat (District Pali) (n = 84)

	Characters	Mean	Range	Standard deviation	Coefficient of variation (%)
1.	Height of plant (cm)	99.10	60-180	27.76	28.01
2.	Canopy diameter (cm)	96.26	35-205	26.15	27.16
3.	Length of leaves (cm)	3.55	2.00-5.50	1.00	28.16
4.	Width of leaves (cm)	1.30	0.50-2.50	0.40	30.76
5.	100 fresh leaf weight (g)	5.94	2.50-9.50	1.77	29.79
6.	100 dry leaf weight (g)	2.12	0.90-3.40	0.64	30.18
7.	Lawsone percent	1.14	0.55-2.00	0.32	38.07
8.	Length of fruits (cm)	0.30	0.20-0.60	0.10	33.33
9.	Width of fruits (cm)	0.53	0.40-0.80	0.13	24.52
10.	Weight of 10 fruits (g)	0.48	0.20-0.71	0.13	27.08
11.	No. of seeds/fruit	36.33	18-63	10.78	29.92
12.	100-seed weight (g)	0.08	0.05-0.15	0.02	25.00

Table 2. Correlation matrix of characters of *L. Inermis*

#	1	2	3	4	5	6	7	8	9	10	11	12
1	1.0	0.35**	-0.1	-0.13	0.18	0.05	0.12	-0.1	-0.15	0.01	-0.17	0.04
2		1.00	-0.1	0.05	0.05	0.02	0.09	0.04	0.09	-0.04	0.03	-0.01
3			1.0	0.75**	-0.0	-0.0	-0.0	-0.1	-0.10	-0.10	-0.12	0.13
4				1.00	0.02	-0.0	-0.0	-0.1	-0.14	-0.07	-0.08	0.01
5					1.00	0.9**	-0.0	0.01	-0.12	0.14	0.03	-0.19
6						1.00	-0.0	0.01	-0.03	0.18	0.12	-0.23*
7							1.00	-0.1	-0.09	-0.02	0.12	-0.4**
8								1.00	0.79**	0.22*	0.21	0.05
9									1.00	0.28**	0.21	0.06
10										1.00	0.27*	0.08
11											1.00	-0.11
12												1.00

#Characters 1 to 12 as in Table 1; *p<0.05; **p<0.01.

cluster distances between the five clusters formed ranged from 2.80 to 3.80 indicating that groups are scattered more or less uniformly. Maximum inter-cluster distance was between cluster IV and V.

Table 3. Inter-cluster distance between centeroids of five clusters of *L. inermis*

Cluster	I	II	III	IV	V
I	0.00	3.61	2.80	2.92	3.10
II		0.00	3.24	3.44	3.40
III			0.00	3.40	3.32
IV				0.00	3.80
V					0.00

The entries included in the present investigation are from same geographical area but from different farmers' fields. This indicates that material from the same region might also have genetic divergence. Cluster III appears to be more promising as it had highest lawsone content as well as plants with best height and spread when compared with other groups.

The observations suggest that there is ample amount of variation in populations of henna in the fields. There is in general high contribution of site characteristics, age, location, etc. when data is collected from naturally occurring populations of trees and shrubs dispersed over wide geographical area. In this crop, however, variation due to environmental parameters is likely to be less as the evaluation was done from well established fields, crop is ratooned every year at almost the same time by all the farmers, and all the fields were located in a small area distributed around Sojat.

Henna is one of the few perennial shrubs under cultivation in arid and semi-arid region. The natural variability still available in the fields means that there is scope of selection for improvement of this crop through on-farm or on-station trials.

Propagation Through Seed

Information on propagation methods of any crop is a pre-requisite for any genetic improvement programme. Our observations during surveys of henna revealed that propagation of henna is done mainly by seeds for commercial cultivation and by cuttings for hedge plantation as this gives flexibility in time of planting and uniformity of plant type.

The seeds have a xeromorphic structure. The optimum temperature range for seed germination is from 25° to 30°C. A study on depth of sowing demonstrated that seeds on soil surface germinate best (88.8%), whereas those sown 2.5 cm deep do not germinate (Bukin, 1983).

Seeds are sown in nursery beds by the farmers during March. They are first soaked in water for 10-15 days and then sown in beds (Anonymous, 1962). Daily irrigation is required in the initial stages. When the seedlings are 5-6 month old and are 30-45 cm tall, they are transplanted in the fields during rainy season (July-September), either singly or 2-3 together. Once established, the plants continue to flourish and yield successive crops of leaves for about two decades. The yield is low during the first 2-3 years. Seed was collected from ten plants from Sojat and nursery was raised using the method being followed by the farmers (Fig. 2).

Fig. 2. Seedlings of henna in nursery

Seed germination of 10 genotypes of henna up to one month after sowing ranged from 44 per cent to 100 per cent with a mean of 73.6 per cent. Per cent survival ability of seedling in these genotypes after one month ranged from 23.1 to 95.0 per cent with a mean of 68.9 per cent.

Variation in seed germination (open vs shade)

Results obtained from the seed germination and survival ability of seedlings of henna sown in March of single genotype showed that germination percentage of seeds grown in 50 per cent shade was higher (90.0%) as compared to those sown in open (60.0%). But survival ability of seedlings in open was more (91.7%) than in shade (50.0%). It appears that due to favourable temperature and humid conditions in shade, germination is better, but these seedlings are less hardy and hence have less survival with reference to those germinated in the open. It may also be due to more disease incidence in moist conditions in shade.

Table 4. Shoot length (cm) and ANOVA in *Lawsonia inermis* seedlings of 10 genotypes at different growth stages

Genotypes	1-month	2-month	3-month	4-month	5-month
LiS-1	4.20	5.33	11.07	16.80	19.53
LiS-2	1.30	4.30	6.53	8.77	10.17
LiS-3	1.00	1.77	2.43	3.67	4.80
LiS-4	1.80	3.43	5.10	7.07	8.57
LiS-5	2.00	3.00	5.73	7.83	9.37
LiS-6	0.60	2.80	4.17	5.13	7.60
LiS-7	1.50	3.17	6.27	8.30	10.37
LiS-8	2.80	4.97	8.00	10.83	12.77
LiS-9	0.90	2.20	5.17	7.17	8.27
LiS-10	5.80	7.33	13.33	16.57	18.63
Mean	2.19	3.83	6.78	9.21	11.00
± S.E.	0.50	1.56	2.98	3.49	3.73
CD 5%	1.13	NS	6.73	7.88	8.42
CD 1%	1.62	NS	NS	NS	NS
Source of variation (df)			Mean squares		
Rep (2)	0.30	3.18	10.12	8.53	7.58
Treat. (9)	8.16**	8.43	31.79*	57.80*	67.12*
Error (18)	0.38	3.65	13.34	18.92	20.96
			Genetic parameters		
GCV	73.57	32.94	36.58	39.39	35.64
PCV	78.80	59.83	65.12	60.88	54.78
Heritability	87.00	30.30	31.50	41.90	42.30
GA	3.10	1.43	2.87	4.84	5.26
GA as % of mean	141.55	37.33	42.33	52.55	47.81

*$p<0.05$, **$p<0.01$

Variation in seedling characters

Seedlings of ten genotypes were raised in net-house by sowing their seeds in March after soaking in water. The analysis of variance of seedling height recorded from first to fifth month growth stages revealed that it differed significantly at 1, 3, 4, and 5-month growth stage (Table 4).

Genotypic coefficient of variation was maximum at 1-month stage (73.57%), whereas, it was more or less same for rest of the stages, varying from 32.94 to 39.39 per cent. The same trend was observed for phenotypic coefficient of variation, where maximum value was for 1-month (78.80%) and for the rest it varied from 54.78 to 65.12 per cent. Heritability was high (87%) at 1-month stage and decreased to 30.30 per cent at 2-month stage, increasing slightly, thereafter in the 3, 4 and 5-month stage. The genetic advance as per cent of mean was maximum for 1-month stage (141.55%), and it decreased in subsequent stages fluctuating between 37.33 per cent to 52.55 per cent (Table 4).

Values of heritability and other genetic parameters for height, in general, were more at one-month stage. High heritability at initial growth stage can be attributed to seed size, seed weight or maternal inheritance (Adams and Jolly, 1977). From 2-month onwards, heritability first decreased and then increased in final stage of growth. Fluctuations in trend of heritability, have also been observed in temperate trees (Franklin, 1979).

The genetic parameters tend to stabilize at 4- and 5-month stages. Thus juvenile selection at 1-month stage may be incorrect and 4-month stage may be earliest stage to undertake any exercise in selection. The validity of such selection can be confirmed only after working out the juvenile-mature relationships.

There were significant differences among genotypes for seedling height, but there were frequent changes in rank of genotypes with growth. Such inferences have also been reported in *Sitka spurce* by Samuel and Johnstone (1979).

Vegetative Propagation

Vegetative propagation was attempted in February-March in net-house having 50 per cent shade using IAA, NAA & IBA singly and

Table 5. Mean values for various characters recorded during vegetative propagation of *L. inermis* using auxins (IBA, IAA, NAA)

Hormone used	Concentration (ppm)	Percentage of rooting	No. of roots/ cutting	Length of roots/ cutting (cm)	Fresh weight of roots/ cutting (g)	Dry weight of roots/ cutting (g)
Control	-	53.3	3.9	3.1	0.43	0.15
IBA	3000	80	2.5	3.5	0.54	0.19
IBA	5000	100	4.8	9.5	0.99	0.35
IBA	7000	100	5.0	8.6	0.76	0.20
IAA	3000	100	8.1	11.1	1.10	0.35
IAA	5000	100	9.7	13.8	1.09	0.38
IAA	7000	100	5.3	12.3	1.23	0.45
NAA	3000	93.3	3.6	9.8	0.88	0.30
NAA	5000	80	8.4	4.6	0.38	0.15
NAA	7000	100.0	4.3	10.4	1.18	0.40
Mean		90.7	5.7	8.7	0.86	0.29

in combination during 2001. The results obtained from vegetative propagation of henna using single hormones (IBA, IAA and NAA) are presented in Table 5. Percentage of rooting over the treatments varied from 53.3 to 100 per cent, with a mean of 90.7 per cent. It was possible to get cent per cent rooting by using IBA or IAA. Best performance for all the observed characters except for number and length of roots per cutting was given by 7000 ppm IAA (Fig. 3 & 4).

Fig. 3. Sprouted henna cuttings in nursery

In the present study it was observed that the exogenous application of auxins increases rooting significantly over control. It may be attributed to the well known fact that auxins play multifarious roles related to the division and elongation of meristem, differentiation of cambial initials into root primordia and the mobilization of reserve food materials by enhancing the activity of hydrolysing enzymes.

Vegetative propagation in different months

Results for vegetative propagation of henna during different months without use of any hormone are presented in Table 6. Rooting per cent ranged from 33.3 to 100 per cent with a mean of 72.8 per cent. Cent per cent rooting was seen in the months of March, July and August. Maximum number of roots per cutting was observed in March (9.3), length of roots per cutting in November (18.8 cm) and fresh and dry weights of roots per cutting in January (0.98 g and 0.30 g, respectively). But overall best performance was shown in the month of July, which showed 100 per cent rooting and values for all other characters were at par with the highest values.

Effect of different months and seasons on rooting have been studied in several plants, viz. *Melia azedarach* L. (Gupta *et al.*, 1989), Korean Fir (Kim and Kim, 1988) and *Prosopis cineraria* (Arya *et al.*, 1993).

There is variation in seed germination in different accessions. In general, it is not difficult to raise nursery, even though initial soaking, proper sowing depth, maintenance of moisture during initial germination stages are some of the critical points. Henna is and easy to root species and vegetative propagation is also not a problem.

Fig. 4. A rooted cutting of henna

Phenology and Reproductive Biology

No genetic improvement or biodiversity conservation programme can be a success in the absence of precise information on mating system, i.e. degree of selfing or out crossing. This information will have bearing on method of sampling during surveys, and method of genetic improvement programme to be followed. How much seed is to be collected, when it is to be collected, how it is to be collected, how many genotypes should be included in the orchard, what scheme of genetic improvement is to be followed, and many other such questions related to genetic improvement can be answered with authority only if one is sure about the phenology and reproductive biology in the species under

Table 6. Mean values for various characters recorded during vegetative propagation of *L. inermis* over various months

Month of planting	Percent-age of rooting	No. of roots/ cutting	Length of roots/ cutting (cm)	Fresh weight of roots/ cutting (g)	Dry wt.of roots/ cutting (g)
January	60.0	6.7	12.1	0.98	0.30
February	93.3	6.9	12.9	0.49	0.13
March	100.0	9.3	10.2	0.42	0.13
April	86.6	5.9	11.3	0.37	0.11
May	33.3	4.5	16.0	0.39	0.10
June	33.3	5.0	13.2	0.40	0.10
July	100.0	6.8	14.8	0.82	0.27
August	100.0	5.2	10.1	0.88	0.29
September	80.0	4.8	11.9	0.41	0.13
October	73.3	4.6	12.6	0.42	0.14
November	66.6	5.3	18.8	0.22	0.07
December	46.6	3.2	16.1	0.19	0.05
Grand mean	72.8	5.7	13.3	0.50	0.15

Table 7. Mean, range and S.D of various fruit and seed characters in Henna

	Mean	Range	S.D.
No. of days required to complete anthesis	16.25	11.50-23.00	3.45
Length of inflorescence (cm)	5.60	4.10-7.20	0.99
No. of flowers/inflorescence	68.30	32.60-90.80	18.35
Pe cent pollen viability at full bloom	85.81	62.50-99.10	-
Length of fruits (cm)	0.3	0.2-0.5	0.1
Width of fruit (cm)	0.5	0.4-0.8	0.12
100 fruit wieght (g)	5.1	3.2-6.2	0.15
No of seeds per fruit	37.8	32.3-49.0	8.24
100 seed weight (g)	0.07	0.05-0.10	0.01

consideration. Hence efforts to generate this information are must for sound genetic improvement programme and efficient utilisation of the genetic variability in the long run.

Shrubs are perennial in nature and there are no distinct (i.e. qualitative) morphological markers in most of the shrubs. Under this situation the only effective way to work out the mating system is either by using traditional methods that regard the classification of the pollen vectors, the structure and characteristics of floral organs, etc. (Fig. 5) or by understanding the crossing behaviour and seed set by imposing different methods of pollination, or by using biochemical or molecular markers (which are normally co-dominant, can be easily quantified, and are hardly affected by the environment). As far as shrubs are concerned information is limited and only recently these studies have received a growing attention. In henna there was no information available on this aspect. The information gathered in the last four years by the authors on phenology and reproductive biology of henna, a monotypic genus under cultivation in arid and semi-arid pockets in Pali and Jodhpur districts of Rajasthan, is summarised here.

Fig. 5. Closeup of a henna flower.

Phenology

Length of inflorescence and number of flowers per inflorescence were recorded on ten well-developed inflorescence on each of the 10 plants. Number of days required to complete anthesis was also studied on ten inflorescence in each of the ten selected plants. Viability of pollen grains in the 10 selected plants was determined using acetocarmine stainability test. For determining flower to fruit ratio, five inflorescence on each of the ten selected plants were tagged. Fruit and seed related characteristics were studied on ten ripe fruits from each of these plants. The results obtained are summarized.

Duration of anthesis : In the ten inflorescence tagged in each of the ten selected plants, number of days required for opening of first flower to last flower, ranged from 9 to 25 days with a mean value of 16.25 days (Fig. 6). Average number of days for anthesis ranged from 11.50 days to 23.00 days in the ten selected plants (Table 7).

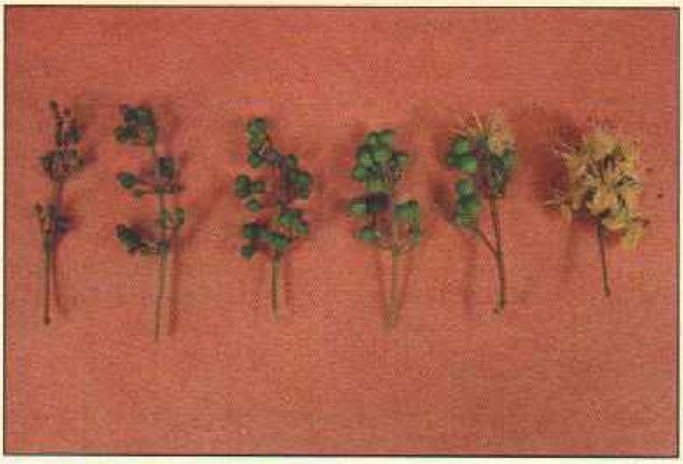

Fig. 6. Different stages of anthesis in the inflorescence of henna

Flowering in most of the plants was observed during September. The average number of days required for complete anthesis were about 16 days. Length of individual inflorescence had a range of 2.40 cm to 9.00 cm with a mean value of 5.6 cm and standard deviation of 0.99. Maximum mean length of inflorescence was 7.2 cm whereas minimum was 4.1 cm.

Number of flowers per individual inflorescence had a range of 27 to 142 with a mean of 68.30 and standard deviation of 18.35. Maximum mean number of flowers (average of ten inflorescence) was 90.8, whereas minimum number was 32.6.

When the flowering was in full bloom, percentage of viable pollen grains in the selected plants ranged from 62.50 to 99.10 per cent with a mean of 85.81 per cent. The results obtained from the pollen viability test of the same plants after 15 days showed that the percentage of viable pollen grains ranged from 45.60 to 92.50 per cent with a mean of 71.19 per cent. Comparison of percentage pollen viability of both the durations indicated that there was a decrease in pollen viability after 15 days of full bloom flowering to the extent of 6.4 to 37.8 per cent in nine plants and increase (21.4%) in only one plant. On an average there was 20.21 per cent decrease in pollen viability.

Fruit related characteristics : Berries are green when young, turn blue black later on and are non-edible. Mature brown berries dehisce into four splits (Fig. 7). Length of fruits ranged from 0.20 to 0.50 cm with a mean of 0.30 cm. Width ranged from 0.40 to 0.80 cm with a mean value of 0.50 cm. Weight of 100 fruits had a range of 3.2 to 6.2 g with a mean value of 5.1 g. Number of seeds per fruit ranged from 32.3 to 49.0 with a mean of 37.8. 100-seed weight had a range of 0.05 to 0.10 g with a mean value of 0.07 g.

Fig. 7. Mature dehisced brown berries of henna

Flowering started in July and continued till mid-September in different plants. Flowering was asynchronous, i.e. flowers were developing at different times on same shrub. One flower out of every 2.34 flowers sets into fruit and the rest drop as such. This may be due to lack of pollinators, or physiological reasons like high temperature and moisture stress, competition for space and limited food resources. Asynchronous flowering and low fruit set has been reported in other arid zone trees like *Tecomella undulata* (Jindal *et al.*, 1985) and *Salvadora persica* (Jindal *et al.*, 1997).

Reproductive biology

To study reproductive biology, ten shrubs growing in genetics nursery of CR Farm of CAZRI, Jodhpur were selected randomly. All the six types of breeding systems were studied and for each system 500 buds were taken. These were: i) natural open pollination, where buds were tagged and allowed to pollinate naturally; ii) cross pollination, where buds were emasculated and were crossed manually with pollen from other flowers; iii) sibbing, where whole inflorescence was bagged with butter paper bags as such; iv) open pollination, where buds were emasculated and left open; v) selfing where single buds were bagged with butter paper bags; and vi) apomixis, where buds were emasculated and bagged with butter paper.

Out of the six modes of pollination studied in henna, maximum fruit set (42.6%) was observed in natural open pollination, followed by hand cross pollination (33.2%), sibbing (14.6%) and open pollination after emasculation (2.4%). No fruits were formed in buds tagged for selfing and apomixis (Table 8).

Table 8. Breeding system in *L. inermis*

Type of pollination	No. of buds tagged	No. of fruits formed	Percentage of fruits formed
Natural open pollination	500	213	42.6
Cross pollination	500	166	33.2
Sibbing	500	73	14.6
Open pollination	500	12	2.4
Selfing	500	0	0
Apomixis	500	0	0

A large number of insects were seen around the plants. Insects belonging to *Zygoptera*, *Coleoptera*, *Catopsilla* sp. and some beetles were predating on larval stages of other insects. On the basis of the observations (Table 8) it can be concluded that henna is both self and cross-pollinated species. Scented flowers, abundance of insects and presence of leaves along with inflorescence all suggest that the mode of pollination may be by invertebrate transport. However, 14.6 per cent fruit set during sibbing suggests lack of self-incompatability and pollination even in the absence of flying insects. Further studies are thus required to establish agents and mode of pollination. According to Miczak (2001) henna is a self pollinating species, its seeds are so hardy that they must be soaked in water to facilitate germination. Hence water seams to be perfect mode of seed migration.

References

Adams, W.T. And Jolly, R.J. 1977. Analysis of genetic variation for height growth and survival in open-pollinated progenies of eastern white pine. *Proceedings of North-east Tree Improvement Conference* 25: 171-181.

Anonymous 1962. The Wealth of India: A Dictionary to India Raw Materials and Industrial Products, (*Brochure Marketing Henna* 1955) Vol. II, CSIR, New Delhi, pp. 47-50.

Arya, S., Toky, O.P., Tomar, R., Singh, L. and Harris, P.J.C. 1993. Seasonal variation in auxin-induced rooting of *Prosopis cineraria* stem cuttings. *International Tree Crop Journal* 7(4): 249-259.

Bukin V.P. 1983. Some biological characteristics of henna (*Lawsonia inermis* L.). *Byulletan Gosudarstvennogo Nikitskogo Botanicheskogo Sada* 50: 63-68.

Darwin, C. 1859. The origin of species. First edition, London.

Franklin, E.C. 1979. Model relating levels of genetic variance to stand development of four North American conifers. *Silvae Genetica* 28(5-6): 207-212.

Gupta, B.B., Kumar, A. and Negi, D.S. 1989. Rooting response of branch cuttings of *Melia azedarach* L. *Indian Journal of Forestry* 12(3): 210-214.

Heybrock, H.M. 1978. Primary considerations: multiplication and genetic diversity. *Unasylva* 30: 119-120.

Jindal, S.K., Bhansali, R.R. and Satyavir 1997. Flowering, fruiting and breeding systems in *Salvadora persica* L. oilseed bearing desert tree. *Journal of Tropical Forestry* 13: 30-34.

Jindal, S.K., Solanki, K.R. and Kackar, N.L. 1985. Phenology and breding systems of Rohida [*Tecomella undulata* (Sm. Seem]. *Indian Journal of Forestry* 8: 317-320

Kim, T.S. and Kim, C.S. 1988. Effects of mother tree ages, timing of cutting and growth regulators on cuttings in Korean fir (*Abies koreana* Wilson). *Research Report of the Institute of Forest Genetics* No.24: 47-56.

Miczak Marie Anakee. 2001 Henna's Secret History The history, mystery & folklore of henna. Publishers Writers Club Press, San Jose, New York Lincoln, Shanghai p 326

Samuel, C.J.A. and Johnstone, R.C.B. 1979. A study of population variation and inheritance in Sitka spruce, results of glass house, nursery and early forest progeny tests. *Silvae Genetica* 28(1): 26-32.

Multilocation Evaluation of Henna for Plant Height, Leaf Yield and Lawsone Content

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The most important economic component in henna is the leaf yield (from farmers' point of view) and high dye content (from industrialists point of view). At present there is no established practice of providing higher prices for leaves having more dye(lawsone), as price in the market is still based on the visual assessment by the buyer. However, purchasers know the areas and fields producing better quality leaves, as they are involved in this trade over decades and have experience regarding quality differences in the produce. They are also aware of variation in quality from different states. For example, the produce from Gujarat or irrigated areas fetches much lower price as compared to that of Sojat. Hence, a multi-location trial comprising of twenty clones selected from different parts of Rajashtan and Gujarat by Dr Jaimini during 2000 and 2001, was established at three different locations viz, Jodhpur, Sardarkrushinagar and Bikaner having average annual rainfall of about 500, 320 and 250mm, respectively. The cuttings of these twenty clones were rooted at Sardarkrushinagar and were transplanted to field at respective stations in randomized complete block design having three replications at each location during August 2001. Plot size was a single row of 3m length accommodating six plants per row. Shrub to shrub distance within and between rows was 0.5m and 1.0m respectively.

Genotype x environment interactions have great role in the manifestation of the characters. Genotype performance may vary significantly over locations and as a breeder the aim is to develop high yielding cultivars with better yield for different areas (Perkins and Jinks, 1968). Such accessions are likely to perform better during different years, as the rainfall in arid and semi-arid region is erratic both in terms of distribution and quantity. At present there is no released variety of henna and only populations raised from seed are in existence at farmers' fields. So one of the prerequisite for undertaking improvement programme was to understand the variation in economic traits under different agroclimatic conditions over years. Data collected on three randomly taken plants from each plot over different locations for plant height and dry leaf yield per plant are discussed here. Lawsone content in dry leaves of different clones in different years was estimated spectrophotometrically at Jodhpur using method of Pratibha and Korwar (1999).

Mean plant height of different accessions of one and two year old plants at Jodhpur, Bikaner and SK Nagar is given in Table 1. Grand mean height of different accessions was maximum (171cm) at Bikaner and minimum (87cm) at SK Nagar, when the plants were one year old. Accession SK Nagar showed maximum height of 270cm at Bikaner where as it had minimum height of 69cm at SK Nagar. At Jodhpur only two accessions Pali and Khedbram performed better. At SK Nagar, accession Malan showed maximum height followed by Khedbram and Pali. Considering the mean height of different accessions of three locations, accession Pali had maximum height of 148cm followed by accession SK Nagar, Malpur and Dhandhuka.

When the plants were two year old, the grand mean height was almost same at Jodhpur and SK Nagar. Accession Khedbram showed maximum height of 174cm at Jodhpur and 175cm at SK Nagar. Considering the mean at both the locations the other accessions which showed better performance in terms of height were accessions Malan, Sarotra, Malpur and Dhandhuka.

Table 1. Plant height (cm) and dry leaf yield (g) per plant of one and two year old plantation of mehndi at different locations.

Accession	One year old								Two year old					
	Jodhpur		Bikaner		SK Nagar		Mean		Jodhpur		SK Nagar		Mean	
	Ht	Ly	Ht	Ly	Ht	Ly	Ht	Ly	Ht	Ly	Ht	Ly	Ht	Ly
Amirgarth	104	19	130	7	82	7	105	11.0	155	28	138	67	147	47.5
Anand	114	72	115	25	81	7	103	34.6	127	44	146	111	137	77.5
Dhandhuka	132	36	205	47	85	9	141	30.6	170	86	145	160	158	123.0
Khedbram	152	47	145	24	106	33	134	34.6	174	82	175	95	175	88.5
Kothara	118	24	180	30	92	10	130	21.3	153	53	147	121	150	87.0
Malan	96	26	142	18	108	12	115	18.6	163	55	185	110	174	82.5
Malpur	132	39	200	42	94	42	142	41.0	161	35	167	200	164	117.5
SK Nagar	91	28	270	64	69	12	143	34.6	140	46	120	73	130	59.5
Sarotra	129	37	155	36	98	16	127	29.6	143	52	188	125	166	88.5
Sidhpur	128	22	146	27	87	10	120	19.6	158	41	143	54	151	47.5
Vasda	99	21	175	49	75	8	116	26.0	130	31	123	112	127	71.5
Ajmer	123	42	158	26	90	16	124	28.0	138	51	144	127	141	89.0
Bikaner	94	38	141	25	73	8	103	23.6	131	71	122	81	127	76.0
Jobner	125	35	122	15	87	9	111	19.6	150	71	140	70	145	70.5
Jodhpur	79	12	215	53	71	9	122	24.6	104	42	112	108	108	75.0
Jadiya	99	19	150*	20*	76*	8*	108	15.7	145	25	146*	49*	146	37.0
Pali	159	48	182	57	103	11	148	38.6	153	98	148	84	151	91.0
Panchotiya	111	51	150	24	91	31	117	35.3	120	80	138	145	129	112.5
Sojat	81	27	200	58	80	10	120	31.6	100	48	112	79	106	63.5
Wav	100	14	217	43	76	4	131	20.3	134	23	120	66	127	44.5
Mean	113	32.9	171	35.3	87	13.8	124	27.1	142	53.1	143	105	143	79.1
SD	22	14.7	39.5	16.2	12	10	-	-	20.01	21.6	22.7	37		-
Minimum	79	12	115	7	69	4	99	11.0	100	23	112	54	106	37.0
Maximum	159	72	270	64	108	42	148	41.0	174	98	188	200	175	123.0

*Values missing, estimated mean on the basis of overall mean values. Ht = height, Ly = dry leaf yield.

Dry leaf yield per plant of different accessions over different locations is given in Table 1. Dry leaf yield per plant after one year was in range of 33-35g per plant at Jodhpur and Bikaner, whereas, it was almost one-third at SK Nagar. Maximum values were recorded for accession Anand at Jodhpur, accession SK Nagar at Bikaner and accession Malpur at SK Nagar. Considering the mean at three different locations, it varied from 11g per plant to 41g per plant. The highest yielder was Malpur (41g) followed by Pali (38.6g), Panchhotiya (35.3g), Anand (34.6g) and SK Nagar (34.6g). The low yielders were Amirgarh, Jadiya, Sidhpur and Jobner.

When the plants were two year old, Mean dry leaf yield per plant of the population was 53.1g at Jodhpur and it was almost double at SK Nagar. Pali accession was best at Jodhpur whereas Malpur showed the best performance at SK Nagar. The other accessions which showed more than 140 g dry leaf yield per plant at SK Nagar were Dhandhuka (160 g) and Panchotiya (145 g). Considering the mean at both the locations, Dhandhuka was the highest yielder (123 g) followed by Malpur (117.5 g) and Panchotiya (112.5 g). All the other accessions were in the range of 37.0 to 91.0 g per plant. Lawsone content of dry leaves of Mehndi at different locations of one and two years old plantation is given in Table 2.

When the plants were one year old, lawsone content ranged between 0.30 per cent for accession Anand and 2.24 per cent for accession Pali. Other accessions Ajmer, Jobner and Vasda had more than 1.3 per cent lawsone content. At Bikaner, lawsone content was more than two times from that of Jodhpur. It ranged between 1.11 to 3.18 per cent. The accessions which had more than 2.8 per cent lawsone of dry leaves at Bikaner were Malan, Anand and Ajmer. The mean values of both the locations had a range of 0.80 per cent for Jadiya to 2.14 per cent for Ajmer. The mean value was 1.78 per cent. The other accessions which had more than 2 per cent lawsone content were Malan, Jobner and Pali.

When the plants were two year old, mean lawsone content was 1.98 per cent at Jodhpur and about its half at SK Nagar. The accessions which showed more than 2.2 per cent lawsone were Amirgarh, Anand, Kothara, Ajmer, Jadiya and Wav at Jodhpur. There was no accession having more than 1.63 per cent lawsone content at SK Nagar. At SK Nagar, the accessions which had a lawsone content of 1.05-1.63 per cent were Vasda, Ajmer, Wav, Kothara and Malpur. Taking the mean values of Jodhpur and SK Nagar, Maximum lawsone content was observed by Ajmer (1.86%) followed by Vasda (1.79%) and Wav (1.72%). The lawsone content at Jodhpur in the first year of establishment was 1.07 per cent, and there was an increase of 85.0 per cent in the second year of establishment.

There seems to be genotype X environment interaction for all the characters as rankings of different accessions varied from location to location and over years of establishment. So, to identify high yielding genotypes with high lawsone content, the accessions should be evaluated at many locations.

At present there are no varieties of mehndi. For immediate gains accessions like Khedbram and Dhanduka can be multiplied for evaluation at farmers' fields.

References

Perkins, J.M. and Jinks, J.L. 1968. Environmental and genotype environmental components of variability. III. Multiple lines and crosses. *Heredity* 23: 239-256.

Pratibha, G. and G. R. Korwar 1999. Estimation of lawsone in henna (*Lawsonia inermis*). *Journal of Medicinal and Aromatic Plant Sciences* 21: 658-660.

Table 2. Per cent lawsone of dry leaves of mehndi at different locations after one and two years of establishment

Accession	One year old			Two year old		
	Jodhpur	Bikaner	Mean	Jodhpur	SK Nagar	Mean
Amirgarth	1.05	2.80	1.93	2.22	0.73	1.48
Anand	0.30	3.06	1.68	2.21	0.65	1.43
Dhandhuka	0.99	2.33	1.66	2.00	0.85	1.43
Khedbram	0.84	2.43	1.64	1.86	0.68	1.27
Kothara	1.30	2.40	1.85	2.32	1.05*	1.69
Malan	1.08	3.18	2.13	2.08	0.85	1.47
Malpur	1.15	2.33	1.74	2.15	1.05	1.60
SK N agar	0.73	1.79	1.26	1.91	0.72	1.32
Sarotra	0.99	2.36	1.68	1.48	1.00	1.24
Sidhpur	1.12	2.08	1.60	1.88	0.65	1.27
Vasda	1.34	2.23	1.79	1.94	1.63	1.79
Ajmer	1.38	2.90	2.14	2.20	1.51	1.86
Bikaner	1.20	2.52	1.86	2.13	0.81	1.47
Jobner	1.72	2.52	2.12	2.07	0.62	1.35
Jodhpur	1.16	2.23	1.70	1.82	0.88	1.35
Jadiya	0.48	1.11	0.80	2.21	1.00*	1.61
Pali	2.24	2.01	2.13	1.67	0.68	1.18
Panchotiya	0.80	2.52	1.66	1.50	0.83	1.17
Sojat	0.79	2.80	1.80	1.85	1.00	1.43
Wav	0.81	2.68	1.75	2.13	1.30	1.72
Mean	1.07	2.48	1.78	1.98	0.90	1.44
SD	0.42	0.36	-	0.23	0.28	-
Minimum	0.30	1.11	0.80	1.48	0.62	1.17
Maximum	2.24	3.18	2.14	2.32	1.63	1.86

*Values missing, estimated mean on the basis of overall mean values.

Traditional Methods of Cultivation and Processing of Henna

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Many shrubs of the region yield products of economic value. *Lawsonia inermis*, commonly known as mehndi or henna is a small elegant bush cultivated in semi-arid areas (Kolarkar *et al.*, 1981) yielding dye, oil and having many other uses like natural pesticide against nematodes, prophylactic agent against skin diseases, skin inflammations, sore throat, etc. (Ali and Sayeed, 1997). It can withstand adverse climatic conditions and can act as an anti-erosion measure on sloping lands. The principal colouring matter, lawsone, is used for dyeing hair, hands or other body parts, clothes, silk, wool, etc. singly or in combination with different plant products or chemicals. The dye/leaves are exported to various European and Arabian countries.

Henna is commonly propagated using cuttings for hedge and by seed for commercial plantation and is under cultivation in some parts of Rajasthan and Gujarat. In Rajasthan, its cultivation is concentrated in Sojat and surrounding areas in Pali district (Kavia *et al.*, 2004) Sojat is also the major centre for marketing and processing of mehndi leaves. The average annual leaf production is about 3-4 lakh quintals, which fluctuates depending upon the rainfall. For example, during the drought of 2002 the production is estimated to be only 10% of the normal. Henna was under cultivation in Faridabad and some other pockets of North India.

In Pali district henna is mainly cultivated as a rainfed crop and cultivation area is concentrated around ancient town Sojat city (historically known as 'Tambavati Nagari'). Sojat and Marwar Jn tehsils of Pali district constitute around 95 per cent area under henna cultivation (Khem Chand *et al.*, 2002), the remaining part is constituted by other tehsils of district and adjacent tehsils of Jodhpur and Nagaur. In this region main product of commercial value in henna crop is its leaves. In Sojat area henna cultivation is considered more than 60-70 years old. It was initially cultivated only by farmers of Mali (gardener) community on small scale during early years but now a day it is cultivated by all and on larger scale.

The main promoting factor in growth of its area was that it requires only one time planting and during later years only two operations are required, viz., one or two intercultural operations and harvesting of leaves. There is no major threat or damage to the crop from grazing animals and thus no fencing and after care is needed. But to harvest rainwater, bunding around the field is practiced. It looks like 'planting once and harvesting for whole life', only with cost of intercultural and harvesting operations. Existing cultivation, processing and trade practices in Sojat are a unique blend of the farmers' innovations, development of marketing procedures and refinement of processing methods. During surveys we interacted with the farmers, commission agents, traders and other persons involved in works related to henna. The traditional practices in vogue in the region are discussed below.

Nursery Raising

Raising henna seedlings from seeds in nursery requires assured irrigation water supply, that too of good quality, in the months of March to June. These preconditions for raising henna nursery don't allow every farmer to go for it, hence mainly farmers around Sojat city, Sojat road and Kantalia (Marwar Jn. Tehsil) villages having irrigation facilities grow henna nursery. Farmer interested in establishing new crop of henna has to make advance booking of seedlings from these nurseries for assured supply of quality seedlings. The nursery growers sell it on monopolistic rates in a good rainfall year when most optimum conditions for henna transplanting prevail. It means seedlings of desired quality i.e. of proper growth stage, thickness of stem, vigour, and better plant type; is not always available. Very tender, or woody (older seedlings) don't give good results in terms of establishment.

The appropriate period reported by farmer for raising nursery is February-March. Seeds are soaked in water for 10-15 days before sowing in the nursery beds. Seed are not sown deep, moisture is maintained for first 15 days. The seedlings can be transplanted in July-September when they attain height of about a foot (6-month old seedlings). Indigenous tillage practices of water harvesting and conservation play an important role in establishment of the seedlings.

Tillage Practices and Transplanting

Pali district, receives average annual rainfall of over 400 mm. Soil type in cultivating area varies from sandy loam to clay loam. There is problematic soil type in some areas. Mehndi is also being cultivated in such problematic areas. Soil has hard strata or *murrhum* at the bottom. It allows more rainwater retention in soil. Major part of cultivation is tillage practices that cover indigenous way of rainwater harvesting in the field and conservation of moisture in soil. Broadly, tillage practices could be grouped as pre- and post-transplanting practices.

Pre-transplanting practices and Transplanting : Farmers harvest the rainwater in field and prepare field by pulverizing the soil. These practices result in better establishment of seedlings and their better growth. Pre-tillage practices adopted by the mehndi cultivators are :

- Erection of 3-4 feet broad bund (at base) and of 4-5 feet height around the field so that rainwater of that field remains in the same field. The bund is provided with cover of thorny material to protect it from the damage. In subsequent years the branches of henna left after shedding of leaves are put on these bunds for their protection. The practice of bunding for rainwater harvesting is also popular in Nawabshah region of Sindh and Bhera and Mailsi of Punjab in Pakistan.
- Deep ploughing of the field is done. Usually mehndi cultivators plough their field 30-35 cm deep so that maximum rainwater percolates in soil. The retained moisture helps in proper survival of transplanted seedlings and their growth.
- Entire field is divided in to fragments of one bigha (about 1500 sq.ft.) with the provision of small bund of 1-1.5 feet height. Locally it is called as "Math". Such *math* checks flow of rainwater in that area and checks erosion. It also facilitates tillage practices.

Transplanting is done by using T-shaped iron rod called '*Halwani*'. Plant to plant and row to row distance observed in a recently planted field was 30 cm or so (Fig. 1). In two year old plants 11-18 tillers could be counted. The number was much higher in old plantations. The transplanting work of henna has various operations including-

Fig. 1. Transplanting of seedlings using *halwani*

- Preparation of seedlings (separation of tender and damaged seedling, cuttings of roots and shoots so that there is about 10-15 cm root and 15-20 cm shoot left after cutting, making bundles (Fig. 2).
- Transportation of bundles to the field,
- Opening of holes (with help of *halwani*) in the field (at desired geometry),
- Putting seedling in the hole,
- Packing the soil around the seedling (very important) with help of wooden stick or heel of foot,
- Checking of proper packing of seedlings

Fig. 2. Ladies making bundles of henna seedlings after cutting roots and shoots

Transplanting work of henna generally has to be completed in very short span of time i.e. within one or two days, for getting high rate of success in establishment of seedlings. The optimum climatic conditions for transplanting of henna include high soil moisture content, cloudy weather and light rainfall. Especially light showers of rain are a boon for establishment of seedlings. Every farmer would like to take advantage of these conditions that generally prevail only for few days during July-August in this region.

Team of persons having well defined roles does the transplanting. Normally one person makes holes using an indigenous implement, another transplants the seedling and the third presses it with the heel or wooden stick. In addition, persons are required for cutting, transporting of seedlings, and few more for other minor operations. If there is one man to open hole in the field during transplanting of henna, it will require at least seven other persons to help him in operations related to transplanting work in prevalent traditional method.

Post-transplanting practices : Farmers usually put their hard labour in standing crop. Primary agronomic practices being followed are cleaning of the fields using *'kudali'*. In cases, where labour is too costly farmers also remove weeds by ploughing using bullocks. Pulverising the soil was the major operation. Deep hoeing practices are adopted for percolation of rainwater in soil. It facilitates conservation of moisture and such tillage practices also allow proper aeration and better root development. These practices are:

- Deep ploughing in standing crop is done with the use of bullock plough as inter-culture operation in between the rows after first year of transplantation and some farmers continued it for many years. Till date many growers used to plough their mehndi fields with bullock driven ploughs. Deep ploughing helped in retention of rainwater in soil and better root development.
- In standing mehndi crop farmers do deep soil working by using special *khurpi/ kasi* (Fig. 3). This is being done after every rainfall during the rainy season from July to mid-September till the crop remains dwarf. This practice is stopped after adequate sprouting of mehndi so that newly sprouted branches may not get damaged. The secret of viable and good crop production is the indigenous tillage practices.

Fig. 3. Weeding and Hoeing using traditional tools

There was hardly any disease and the farmers did not spray the crop with any insecticide. It was reported that during good rainfall years castor semi-looper appears and damages the crop, at times severely. Even if the crop is fully defoliated farmers cut the branches in October so as to get new growth during next year. A pollen feeder *Mylabris pustulata*, commonly known as blister beetle was seen hovering on *L. inermis* flowers in large numbers during the survey. No farmer reported the use of any fertilizer.

Harvesting and Threshing

The branches of the shrub are cut near the base (6-8"). The cutting is done mainly by women who use leather glove in the left hand and sickle (non-serrated half circle) in the right hand (Fig. 4). The harvesting of 1-yr old plants is done bit carefully,

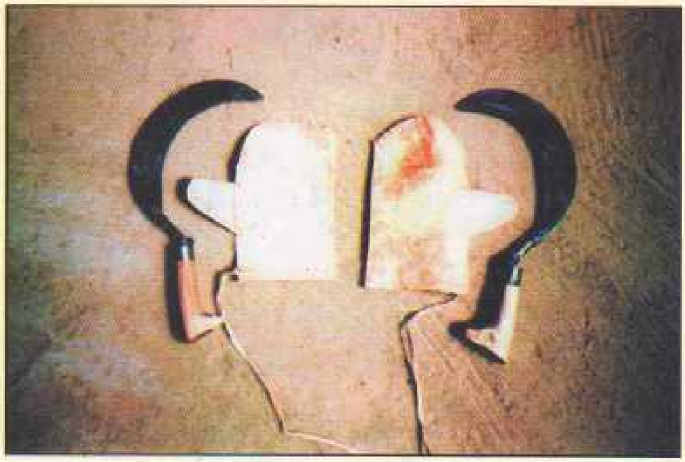

Fig. 4. Sickle and leather glove - the traditional tools for harvesting henna

once old, it is ruthless. Most of the farmers harvest in September-October. After harvesting, the branches with leaves are collected on any clean place near the crop field for sun drying. These are turned upside down daily for 3-5 days using wooden implement '*Bewla*' (having about 6 ft handle and a fork in the front). Thereafter these are thrashed using the same implement. Leaves dry but branches stay flexible. The general view was that if the plants are harvested early, the quality of leaves is not up to the mark. The branches don't seem to have much utility. Mainly these are thrown over the fence (Fig. 5) to raise it as mentioned earlier or are used as fuel for making bajra chappatis (*sogra*). In India mostly men undertake the job of transportation of harvest to the threshing floor and then to market. In henna growing parts of Pakistan, camel is still used frequently for this purpose.

Fig. 5. Crop residue (branches) of henna over field bunds

Management of established henna plantation thus involves operations like one/two hoeing and weeding, harvesting, threshing and filling of bags at threshing floor. However, these are linked with rainfall and carried out by all the cultivators at the same time. Consequently there is shortfall of skilled labourers and the competition for hiring labourers among the cultivators raises labour charges to a great extent. At the time of hoeing and weeding the labour charges go up to Rs. 150-200 per labour per day as compared to normal rate of Rs. 60-70. Further at the time of harvesting this could go as high as a woofing Rs. 350-500 per labour per day. In this situation large farmers (having more capital to invest) are able to carry out operations in time, but the medium farmers are constrained and consequently operations are delayed causing losses in the form of low overall production and productivity. Small farmers generally do not hire labour and only family labour is used (Fig. 6). The time of harvest is most crucial because if farmer delays harvesting he may loose produce in the form of shedding of leaves, if he goes for untimely /early harvesting, there is a risk of spoilage of harvested leaves in the field due to even a very light shower of rain or moist (humid) weather.

Fig. 6. Family of a small farmer harvesting henna crop

As the crop area is concentrated in few tehsils of Pali district much innovations in the direction of mechanisation of various operations has not been made and farmers are left to follow the traditional/conventional method of hoeing, weeding and harvesting. The hoeing and weeding in the crop is carried out simultaneously in one operation using the local/ indigenous hand hoe (having 8-9" inches broad sharpened blade at one end other end narrowed to have long wooden handle of 4 - 5' ft length, locally called as 'kassi') and one normal labour only does the operation in 0.05 ha area per day, thus complete hoeing and weeding in one ha will need around 20 man days. The traditional method of harvesting using extra large size heavy weight sickle having broad blade, is time consuming and needs skill. Harvesting in one ha takes around 12.5 to 15 man-days that too only through skilled labourers. Collection of the harvest and its transportation to threshing floor takes around 20 man-days per ha. The threshing of harvest after one day by beating with local wooden tools like a rake/simple long wooden sticks to separate leaves from the stalks takes 6-7 man-days per ha.

Henna requires very good rain for establishment but a very light shower of rain at the harvest is enough to spoil the crop. Henna is harvested generally after withdrawal of monsoon i.e. last week of September to second week of October. Natural greenish colour of leaves of henna in presence of moisture changes to rusty; this happens even if the leaves are filled in bags but exposed to moistened air. The price of such produce (leaves) goes down drastically in the market. In general farmers complete harvesting in shortest possible time period to escape such situation. Some farmers harvest very small area at a time so as threshing and filling of bags can be done within next two-three days. Effluent farmers cover their produce either with plastic sheets or tarpaulin.

Quality of Produce

Sojat is famous for the quality of leaves. The bags used for filling the leaves are made by stitching two bags and can accommodate about 40 kg (a maund) of dry leaves. One can see women and few men involved in marking such bags locally in Sojat City (Fig.7). The quality of leaves determines the price. At present the quality of leaves is assessed by the traders on visual basis, experience, origin, etc. Henna, being a commercial cash crop and having high risk of quality deterioration due to various factors like exposure to rain, sunlight and long storage, needs better storage and marketing facilities. The henna growing areas of Pali district have a sub-mandi yard (govt. regulated market) in Sojat city, where cultivators sell their produce. During our visit to Sojat market meant for trading of henna leaves, we could collect three types of samples as differentiated by the traders. These were :

Small green leaves (Grade 1): This was the produce having uniform green leaves harvested from mature shrubs (in October). Lawsone content in these was 3.0 per cent as estimated using the method of Pratibha and Korwar (1999). The values of lawsone are essentially for comparisons and are not absolute.

Yellow-green mosaic leaves (Grade 2): These were also harvested from mature shrubs but early (September) when leaves were not that stiff. According to market persons, they have no difference with respect to the best quality leaves as far as colour content is concerned but the price of such leaves is low. The lawsone content in these was 2.6 per cent, i.e. only 14 per cent less than grade 2 leaves.

Light to dark leaves (Grade 3) : Leaves harvested from mature plants but got exposed to rains. These were considered to have only 60% of the colour by the traders. The lawsone content in these was only 2.08 per cent i.e. 30 per cent less than the grade 1 leaves.

Storage

The produce from henna being in the form of dry leaves is voluminous. This factor results in requirement of large area for storage of produce that should be covered to protect the produce from exposure to rain/moisture and direct sunlight. Some big farmers have big sized tin sheds or halls to store the produce, but majority of farmers cannot afford such structures owing to financial constraints. This compels them to sell their produce at the prevailing market price. Though mandi yards have tin sheds but these are not sufficient for the produce of the area and the voluminous produce is put in open and consequently every year it results in losses of lacs of rupees.

Marketing

The price of henna leaves fluctuates to a very wide range, as it is not supported or regulated by government. In a good production year the price goes as low as Rs. 1000-1200 per quintal in comparison to a low production year when price goes as high as Rs. 2500-3000 per quintal or even more. The lack of storage facility further aggravates the situation.

There is lack of standard marketing procedures and facilities. The farming community is generally not satisfied with the mandi procedures and facilities. For example, a deduction of 3.5 to 4 kg is made per bag of 35-40 kg in lieu of bag's weight and inert material, etc. The sale procedures in mandi is 'open auction'. The traders put their hands in upper portion of any bag and pick part of produce and just on that basis decide the quality of henna. Average farmer complains that quality of his produce is generally under estimated and that fetches him low price. As already mentioned the mandi yard doesn't have sufficient shed for storage of produce of farmers thus they have to sell their produce as early as possible at prevailing rates.

Processing

At present there are above 25 major factories at Sojat for processing of leaves. In these factories the material is first cleaned in rotatory drum having sieves of three different grades where dust and fine particles get removed. Thereafter, the

Fig. 7. Men and Women stitching jute bags in Sojat market

leaves are blown out of the machine. The berries/stones or heavy soil particles are left near the fan. The cleaned leaves are then threshed in a thresher where fine mixture of leaves is obtained as one can get by crushing a dry leaf in hand. This mixture is free from dust, branches, soil, etc. This leaf 'choori' is then pulverised in pulverisers. Prior to the pulverisers, machines having big circular grinding stones were in use. Today these circular stones can be seen lined up outside the factories. The fine powder is blown up and is sucked at the other end. Here also some debris which is heavy gets accumulated at the base and is removed. As excessive heating can lead to loss of colour, pulverisation is normally done by many during night. During the cleaning of leaves and pulverising 12-18 per cent loss of matter was reported. It is mainly the dust, fruits and seeds.

There are few factories that can give the mehndi at the low rate. The cleanliness is compromised and leaves of other plants are also some times added. Leaves of *khejri* (or possibly jal) are commonly added. These days leaves of *amli* (*Cassia auriculata*, whose bark is used for tanning leather) are also used as adulterants. Most of the factories provide pure henna powder. Some of them, however, mix green colour after processing to give the powder an attractive look.

Henna growers of the region through their experience, observations and as per local conditions have evolved methods to get sustainable income during various conditions. Henna has been a boon to the people of the region. Even though it is an important dye crop, but its cultivation is in a small localized region. There were no reports of gluts of leaves in the market. Limited planned research has been done on this shrub species.

References

Ali, R. and Sayeed, S.A. 1997. Lawsone: phenolic of henna and its potential use in protein-rich foods and staining. *Antinutrients and Phytochemicals in Food*, Washington, pp. 223-244.

Kavia Z.D., Verma S.K. and Singh H. 2004. traditional methods of cultivation of hena(in hindi). *Bhartiya Krishi Anusandhan Patrika* 19: 168-174.

Khem Chand, B.L. Jangid and B.L. Gajja 2002. Economics of henna cultivation in semi-arid Rajasthan. *Annals of Arid Zone* 41(2): 175-181.

Kolarkar, A.S., Singh, N. and Shankarnarayan, K.A. 1981. Mehendi (Lawsonia inermis L.) cultivation in normal and degraded lands of western Rajasthan. *Indian Journal of Soil Conservation* 9(1): 71-74.

Pratibha, G. and G. R. Korwar 1999. Estimation of lawsone in henna (*Lawsonia inermis*). *Journal of Medicinal and Aromatic Plant Sciences*, 21:658-660.

Agrotechniques for Henna (*Lawsonia inermis* L.) Cultivation

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Henna (*Lawsonia inermis* L.) or mehndi is a highly branched perennial shrub cultivated as ratoon crop under cutting management due to its good regeneration ability. Its dye bearing leaves constitute the main economic produce. The leaves of this shrub are small, simple and opposite. This plant is one of the oldest sources of plant dye compound known to man. Its leaves contain the reddish orange dye named lawsone that has been used since biblical times as a cosmetic dye. It also served as a textile dye until the advent of synthetic dyes. Many ayurvedic and unani medicines are based on the curative properties of henna leaves and other plant parts. Henna is a fast growing small shrub planted as highly dense plantations on agricultural or degraded wastelands, saline soils, shallow gravelly lands, etc. Its plantations are sustainable under coppice system for 15-20 years.

Henna has been under cultivation in India since 12th century. For long it was grown in the arid and semi-arid tracts of Punjab, Madhya Pradesh and Gujarat. However, as other crops replaced henna in these regions its cultivation has gradually shifted to the arid fringes of Rajasthan. Currently, Pali district in Rajasthan has the maximum area of about 35,000 ha under henna with an annual production of about 35,000 tones dry leaves worth Rs. 70 crore. Sojat area is the main centre of henna cultivation and processing in Pali district. Additional produce comes from the old farms and field boundary plantations in Gujarat and Madhya Pradesh.

Selection of Plant Type

The yellow flowered henna is cultivated in arid Rajasthan as dye-crop, of which two types are recognized. They are locally known as desi and muraliya type. The desi type has a leafy canopy with larger green leaves while the muraliya type has a woody canopy with small leaves of distinctly greyish green colour and hard pointed branchlets. The desi type is favoured for cultivation in view of its higher leaf yield potential.

Soil and Climatic Requirement

Henna can be grown on wide variety of soil and climatic conditions. However, deep, fine sandy or medium textured well-drained soil is considered best for henna cultivation. This crop shows resistance to soil salinity. The henna fields in Pali district of Rajasthan have 40-60 cm deep sandy loam to clay loam soils with calcareous substratum with soil pH ranging from 7.7 to 9.0. This region lies in the transitional belt of arid western Rajasthan that receives an average annual rainfall of about 450mm. It requires moderate temperature of about 30-35°C during active growth period. As a dye crop, it requires hot, dry and sunny weather conditions with RH <50% at maturity for higher dye content.

Nursery Practices

Henna can be propagated through cuttings as well as by seedlings. Propagation through cuttings is the main method used for raising hedges. However, seedlings are preferred for field planting due to their higher survival rate and economy. Henna seeds have a hard seed coat and therefore, seeds are treated before sowing to break hard seed coat. Normally seeds are soaked in water for 8 to 10 days, with frequent changing of water that gives about 20 per cent germination. Soaking of seeds in 3.0 per cent salt solution for 24 hours results in 60-70 per cent germination. Nursery beds about 30 m^2 size are prepared and one kg seed mixed with fine sand are broadcast in these beds. Sowing is done during first fortnight of March, when temperatures are optimal for germination (25-30°C). About 6-8 kg seed is needed to raise seedlings for transplanting one hectare. To meet the nutritional need of seedlings 10 t FYM ha^{-1} is applied to the nursery beds before sowing.

The henna seedlings are very delicate, extremely sensitive to water stress and hot desiccating winds and grow slowly for first 30-40 days after emergence. Therefore, during this period, the beds are watered regularly once every two days in the evening or during night; later irrigation is reduced to once every 3-5 days depending on weather. Windbreaks are provided around the nursery for protection from hot dry winds.

Regular weeding is practiced by hand picking and suitable control measures are adopted to check seedling diseases like damping off, bacterial leaf spot, and leaf blight. Henna nurseries are often affected by dodder infestation. As the fruiting bodies and seed of this higher plant parasite resemble those of henna it is difficult to eradicate it from seed lot. Accordingly, to avoid dodder infestation the seed for nursery should be obtained from clean fields. In about 3-4 months the seedlings attain 30-40 cm height and are suitable for transplantation in the field.

Transplantation

Transplantation is carried out during rainy season in the month of July-August. One deep ploughing using mould board or disc plough is followed by disc harrowing and planking. Before leveling, one final ploughing with country plough is considered desirable. Seedlings to be transplanted are cut from both ends so as to leave about 10cm of both main stem and tap root, and the root portion is drenched with anti-termite pesticide. Thereafter, the seedlings are transplanted in the field at a spacing of 30 x 30 cm in peg holes as traditional practice. Proper placement of the transplants and soil packing along with receipt of rainfall soon after transplantation are vital for the establishment of seedlings. Trials at Central Arid Zone Research Institute, Pali showed that planting at 45 cm x 30 cm spacing gave highest dry leaf yield followed by 60 cm x 30 cm spacing (Table 1).

Table 1. Effect of crop spacing on leaf yield (kg ha^{-1}) of henna during successive harvests under rainfed conditions at Pali-Marwar (Rao *et al.*, 2003)

Spacing	1999 (354 mm)	2000 (245 mm)	2001 (500 mm)	Pooled
30 x 30 cm	401.2	403.1	1242.3	682.2
45 x 15 cm	295.4	386.7	1118.8	600.3
45 x 30 cm	509.6	803.4	1399.7	904.2
60 x 15 cm	338.9	376.2	1138.2	617.8
60 x 30 cm	426.2	778.1	1398.2	867.5
CD (P=0.05)	74.2	86.2	205.7	**

Traditional and improved plant arrangements are shown in Fig. 1 and 2, respectively. Experiments at Pali and Jadan are shown in Fig. 3. and 4. This indicates that at wider spacing the assimilate supply for an individual plant was sufficient to sustain numerous vegetative sink (Arnon, 1992). These spacing are also suitable for mechanical cultivation. Recent studies conducted at CAZRI, Pali revealed that 30 cm wide and 15 cm deep furrows opened at 60 cm distance for planting henna seedlings helped in rainwater conservation and better establishment of seedlings. In subsequent years the space between two rows can be used to conserve rainwater and controlling weeds by opening deep furrows. This technique may prove highly efficient in rainwater conservation especially during years of low rainfall to attain sustainable production of henna and also for cultivation of henna in areas receiving less than 400 mm rainfall.

Fig. 1. Traditional planting practice of henna

Fig. 2. Improved planting practice of henna

Fig. 3. Henna cultivation at CAZRI, RRS, Pali

Fig. 4. Henna trial at CAZRI experimental area, Jadan

Nutrition

At present very little or no fertilizer is being used for henna cultivation in our country. In trials conducted at Central Arid Zone Research Institute, RRS, Pali henna crop responded to nutrition. Application of farmyard manure at 5 t ha^{-1} proved beneficial in terms of seedling establishment and dry leaf yield and quality (Table 2). It should be mixed well in soil during field preparation before transplanting. It is essential to apply nitrogen and phosphorus. Nitrogen fertilization stimulates tiller growth and leaf development and Phosphorus plays important role in formation of roots, their proliferation and improvement in their functional activity.

Table 2. Effect of Farmyard manure on dry leaf yield (kg ha^{-1}) of henna under rainfed conditions at Pali-Marwar

Farmyard manure	Leaf Yield (kg ha^{-1})
No FYM	970
FYM at 5 t ha^{-1}	1099

After the establishment of plants, N should be applied every year at 60 kg per hectare in two equal splits, first just after the first rain and second split about a month later (Table 3). Phosphorus at 40 kg P_2O_5 per hectare should be applied and mixed in the soil entirely at a time in the crop root zone along with first split of N application. Henna crop also shows response to the application of secondary nutrient and micronutrient. However, nutrient x environment interactions seem to play significant role in the overall response of the crop to applied nutrients (Rao *et al.*, 2004).

Table 3. Effect of nitrogen levels leaf yield (kg ha^{-1}) of henna during successive harvests under rainfed conditions at Pali-Marwar

Nitrogen (kg ha^{-1})	1999 (354 mm)	2000 (245 mm)	2001 (500 mm)	Pooled
0	382.2	510.9	1145.7	679.6
30	395.8	543.7	1226.7	722.1
60	390.4	567.9	1326.6	761.6
90	408.6	575.6	1339.3	774.5
CD (P=0.05)	NS	NS	144.3	*

Irrigation

Henna is usually grown as a rainfed crop during kharif season. Therefore, to maximize rainwater harvest and moisture availability, henna plantations are bunded along the periphery of the fields. However, in absence of adequate rainfall or prolonged drought spell during rainy season, irrigation is beneficial. And where irrigation facilities are available, second harvest is also possible and the crop is usually irrigated at an interval of 15-20 days. Before the crop reaches physiological maturity, it is left un-irrigated for about a fortnight to achieve high dye content in the leaves. Besides providing a second crop during *rabi* season, irrigation also enables raising an intercrop of wheat in the henna fields. Frequent irrigation is, however, believed to decrease the leaf quality by lowering dye content. Singh and Mann (1979) minimized the installation cost and water use by 50 per cent using single lateral between two or three rows in vegetable crops. In such a case plants within rows are usually spaced closer than normally recommended. Drip irrigation system in henna (Fig. 5) designed to provide one lateral for each pair of rows and one dripper between two plants i.e. one dripper will provide irrigation to four plants. This system enables two additional harvest of henna crop apart from main season crop by maintaining restricted deficit irrigation.

Fig. 5. Henna under drip system of irrigation

Interculture

Weeding and soil working are essential to conserve soil moisture in the field. At least one hoeing-cum-weeding is required after a month of transplantation or growth in ratoon crop. Pre-emergence application of Atrazine at 1.0 kg *a.i* per hectare will control most of the broad leaf weeds and annual grasses. Mechanical operations are avoided in the new plantation to prevent injury to the fresh transplants. Interculture in the ratoon crop, however, is possible employing bullock or tractor drawn implements, if rows are spaced at 45 or 60 cm, respectively.

Crop Protection

Termite is the major pest of henna in the field. It can be controlled by soil application of Chloropyriphos (10%) or Furadon 10G at 25 kg ha^{-1} during field preparation and by dusting of standing crop with Chloropyriphos or Furadon. Under prolonged moist and cloudy conditions there may be high incidence of semi-loopers that can be controlled by foliar spray of Quinalphos 30 EC at 1.25 litre ha^{-1}.

Harvesting and Yield

Henna takes about 1-3 years to become fully established in field. Economic production of leaves start from the third year onwards that continues for the next 15-20 years. The first harvest is taken at about 100-110 days in the main growing season. Leafy branches are cut 8-10 cm above the ground (Fig. 6) using sharp heavy sickle and protective glove made of tough leather.

The crop is harvested when the leaves are fully mature and yet retain their green colour. This stage is indicated by the onset of ripening of the capsules as well as by the leaves on the main stems that begin to turn yellow and fall. Harvesting is also dependent on the rainfall as dry period of a fortnight is essential before the harvest of the leaves. Late rains delay the harvest of the crop. To achieve better vegetative growth and also get produce of better quality, farmers generally resort to removing flowers and immature fruits before the harvest, especially when there is delay in the harvest due to late rains. The harvested branches are fully dried in the open (preferably in shade) and then beaten on the ground to collect the leaves. Drying during the months of Oct.-Nov. generally takes 4-5 days. Dried leaves are finally stored in gunny bags in a dry place for marketing. For storage and transport big bags prepared by stitching two gunny bags are commonly used by the farmers and these can accommodate about 40 kg leaves.

Fig. 6. Freshly harvested henna field

The average dry leaf yield under rainfed conditions in Pali region is about one tonne per hectare; higher yield up to 2.5 t per hectare is obtained under irrigation (Anonymous, 1987). Under the warm continental climate of Azerbaijan the crop yields around 1.5 t per hectare dry leaves.

Prospects

There is considerable scope of growing henna for the economic development of the arid regions. Due to its drought hardiness it can be cultivated on land that are drought prone, marginal or unsuitable for arable cropping to give assured economic returns at low cost or investment (Khemchand *et al*., 2002). The semi-arid transitional plains of Luni basin in Rajasthan i.e. the area extending from the northern foot hills of the Aravalli to the sandy arid plains of the west, holds good promise for henna cultivation as a cash crop in a systematic manner. Further, its persistence in the field might help to check or even reverse the desertification processes in vulnerable areas.

References

Anonymous, 1987. *Handbook of Agriculture*, pp. 1221-22. Indian Council of Agricultural Research, New Delhi.

Arnon I. 1992. *Agriculture in drylands: Principles and practices*. Elsevier Science Publishers BV, The Netherlands. pp. 725-746.

Khem Chand, B.L. Jangid and B.L. Gajja (2002). Economics of henna in semi-arid Rajasthan. *Annals of Arid Zone*, 41(2): 175-181.

Rao S.S., P.K. Roy, and P.L. Regar 2003. Effect of crop geometry and nitrogen on Henna (Lawsonia inermis L.) leaf production in arid fringes, *Indian. J. agric. Sci.* 13(5): 283-5.

Rao S.S., P.L. Regar and P.K. Roy 2004. Crop weather interaction on henna (*Lawsonia inermis* L) leaf production in arid fringes. Abstracts: *In National Symposium on Geo-informatics Applications for Sustainable Development*. February 17-19, 2004, WTC, IARI, New Delhi.

Singh S.D. and H.S. Mann 1979. Optimization of water use and crop production in an arid region. *CAZRI Research Bulletin No. 1*, pp. 3-14.

Potential of Planting Configuration and Water Harvesting in Improving the Production of Henna in Arid Fringes

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Henna or mehndi (*Lawsonia inermis* L. syn. *alba* Lam.) a perennial shrub (Fam. Lythraceae) is cultivated for obtaining lawsone from leaves and perfume from flowers. Henna leaves were possibly used in ancient Egypt, much as they are today, in the form of a paste to colour the palms of hands, the soles of feet, the nails and hair around 2000 BC. The hands, feet and hair of several mummies were found to be stained red with henna (Gode, 1999). However, women's henna traditions may have since been continuously practiced for as long as 9000 years ago (Jones, 2002). It is cultivated in Egypt, Sudan (Africa) Pakistan, Yemen and India (Asia). In India it occupies about 40,000 ha area out of which 35,000 ha alone is in Pali district (Sojat and adjoining tehsils). It is also cultivated in Gujarat in the form of hedges on the field bunds. Henna cultivation at Kannauj and Ujjain is for henna perfume. Around 90 per cent of total production of henna dry leaves is produced in Pali district of Rajasthan and Sojat is a major centre for its processing and trading in India. Export to other countries is done from Delhi and Mumbai.

The biophysical limit of henna in terms of annual rainfall is 200-4200 mm (Anonymous, 2004). The climate as well as soil type and topography of the area favour henna cultivation in the region. Farmers traditionally plant this crop in 30 cm x 30 cm spacing. The productivity varies from 400 kg ha^{-1} in low rainfall years to 1000 kg ha^{-1} in good rainfall years. Higher plant population in closer row spacing compete for water, nutrient and light and hence early drying and shedding of lower leaves cause considerable loss in yield particularly in low rainfall years.

The shortage of water to rainfed crops can be resolved by increasing total water availability to crop plants or restricting evaporation losses relative to transpiration by integrating various management options like soil moisture conservation, planting configurations, eliminating weeds and judicious application of nutrients (Singh and Saxena, 1998). Such information is meagre or lacking in henna cultivation in India or elsewhere in the world.

The use of the concepts of planting configurations and *in situ* moisture conservation and their integration in optimising the production of henna in arid fringes (District Pali) are described below.

Climatic and Soil Characteristics of Arid Fringes

Climatic characteristics

Pali district lies between 24°45' - 26°29' N and 72°47' - 74°18' E at 212 meters above MSL. The climate of Pali district, a typical site on the fringes of arid in Indian part of the Thar Desert, is arid to semi-arid. The rainfall pattern of Pali, Sojat and Marwar is shown in Figure 1. The average rainfall for Pali (1968 to 2004) and Sojat (1964 to 2004) is between 400 to 420 mm while at Marwar it ranges from 460 to 550 mm (1980-2004). The minimum rainfall for producing a crop in dry farming area with summer rainfall pattern is estimated as 500 mm (Koeppe and Long, 1958). Number of years having rainfall below or equal to 500 mm was 28 out of 37 for Pali, 29 out of 41 for Sojat and 15 out of 25 years for Marwar. Such frequent occurrence of low rainfall years led to exhaustion of groundwater levels in the region. Around 85 per cent of annual rainfall occurs between July to September in arid fringes. Temperature is between 30-35°C with RH >80% during July-August. Bright sunshine (cloud free sky) 8.5-9.4 hours with 36-40°C temperature and RH <50 % from mid September to early October is common feature in the region.

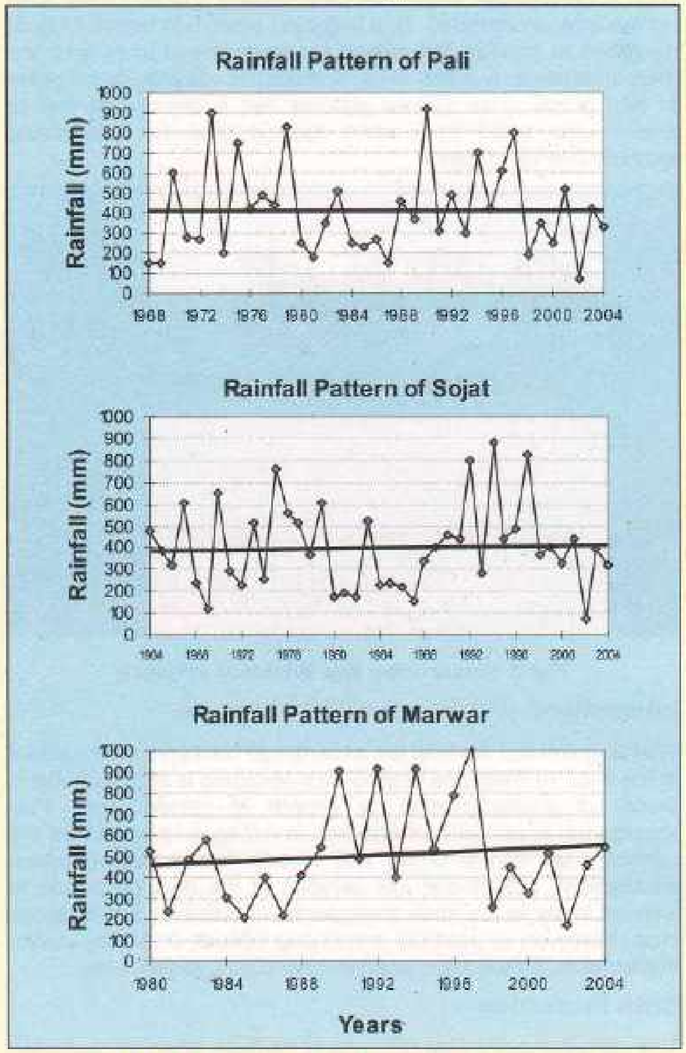

Fig.1. Rainfall pattern of Pali, Sojat and Marwar Jn

Soil characteristics

The soils are sandy loam with pH 8.1, EC 0.16 dSm^{-1}, organic carbon 0.37%, low available N 213 kg ha^{-1}, available phosphorus 11.0 kg ha^{-1} and exchangeable K 250 kg ha^{-1}. The soil has 45% sand, 36% silt, 19% clay, 1.36 -1.49 g/cm^3 bulk density, 18.5% (w/w) field capacity and 8-6% (w/w) permanent wilting point (15 bar tension). The silica bonding in between clay particles leads to crusting as a result most of rainwater is lost in the form of runoff. Also low infiltration rate 10-12 mm hr^{-1}, causes runoff during heavy rains. The Aravalli range with small hillocks at the arid fringes coupled with sloppy land causes fast runoff in the region. Hence farmers practice bunding around the field to conserve water.

Planting Configuration

Higher plant density has been a shotgun for enhancing transpiration relative to non-growth related evaporation losses in high rainfall areas or irrigated condition (Mukammal and Bruce 1960, and Blum, 1970)

In arid region, particularly rainfed condition, dense canopy growth may be disadvantageous as it may exhaust the available soil moisture from root zone during drought (Singh, 1977). So in such areas, one has to be more cautious in deciding optimal plant density and row spacing for sustainable production.

Hence an experiment was conducted to evaluate the effect of row spacing and plant density on henna from 1997 to 2001 established through seedling in 1996. In 1997, 719 mm rainfall was received during cropping season. Higher plant densities in 30 cm x 30 cm, 45 cm x 15 cm, 60 cm x 15 cm and 45 cm x 30 cm spacing produced 27.5, 21.7 16.9 and 12 per cent higher yield of dry henna leaves than that to 60 cm x 30 cm in one year old henna crop during 1997 (Rao *et al.*, 2003).

In subsequent year (1998) low rainfall (145.1 mm) caused poor sprouting owing to abiotic (low moisture content) stress. In good rainfall years like 2001, 45 cm x 30 cm and 60 cm x 30 cm spacing yielded 12.7 and 12.6 per cent higher produce than 30 cm x 30 cm spacing. But in low rainfall years (mean of 1998, 99, and 2000), 45 cm x 30 cm and 60 cm x 30 cm spacing, provided 64 and 50 per cent higher leaf yield, respectively, than that of 30 cm x 30 cm spacing. Mean of five years data (1997 to 2001) also revealed that wider row spacing performed better over closer row spacing (Table 1).

Table 1. Mean dry leaf yield and biomass production of henna (1997-2001) as influenced by row spacing and plant density

Yield parameters	Spacing (cm)					CD
	30x30	45x15	45x30	60x15	60x 30	
Dry leaf (kg ha^{-1})	557	505	693	509	653	*
Biomass (kg ha^{-1})	1288	1228	1621	1237	1516	**

CD = *, ** (P = 0.05 and 0.01) based on logarithmic transformation.

Our findings are in confirmation to observations made for sorghum by Tomar and Saini (1979) and for pearl millet and arid legumes by Shankarnarayan and Singh (1985). Though 45cm x 30cm produced highest yield but it was at par with 60cm x 30cm under Pali conditions. The later planting arrangement had a population of 56,000 per hectare. Vyas (2005, personal communication) also reported that a population of 50,000 plants per hectare was optimum under prevailing rainfall condition at Bhuj (Kutchchh).

Another way to reduce crop canopy exposure to solar radiation is to change the spatial arrangements of plants from conventional regular row to double or triple row planting. By bringing in the highest packing fractions of space between rows, paired row or triplet row planting may suppress early plant growth (Arnon, 1975), increase root elongation (Haynes *et al.*,1959), enhance senescence of mutually shading lower leaves in the row zone (Burch and Johns, 1978) and result in efficient use of soil moisture.

Keeping this principal in mind an experiment comprising these planting configurations along with *in-situ* moisture conservation technique on the production of henna was initiated at Jadan (CAZRI, Pali) in 2003. Plant density in 60 cm x 30 cm spacing standardized by Rao *et al.* (2003) and Vyas (2005) was considered to be an optimal density for experimentation in arid fringes.

Planting in 60 cm regular rows (RR) was compared with paired row, triple row, inter row, inter paired row and inter triple row water harvesting. Row to row distance and plant-to-plant distance within row were kept 60 cm and 30 cm, respectively in RR and inter row water harvesting treatments (IRWH).

In paired row planting geometry, distances were 45 cm between row-to-row, 90 cm between row pairs and 25 cm within rows. In triple row distances were 25 cm between row-to-row, 60 cm between pairs of triple rows and 40 cm as intra row spacing. These three planting configuration were integrated into water harvesting in another set, wherein 60, 90 and 60 cm space between row (RR), row pairs (paired row) and triple row (Tr), respectively was used to open 30 cm wide and 15 cm deep furrows before the onset of monsoon (Fig. 2). Tractor operated furrow making in IRWH is shown in Fig. 3 and 4. Thus, there were six treatments. Henna without water harvesting is shown in Fig. 5. In first year, plants were planted in furrows in inter row water harvesting treatment. While in IPRWH and ITRWH, the space between pairs of double or triple row was raised a little to conserve water in planting zone.

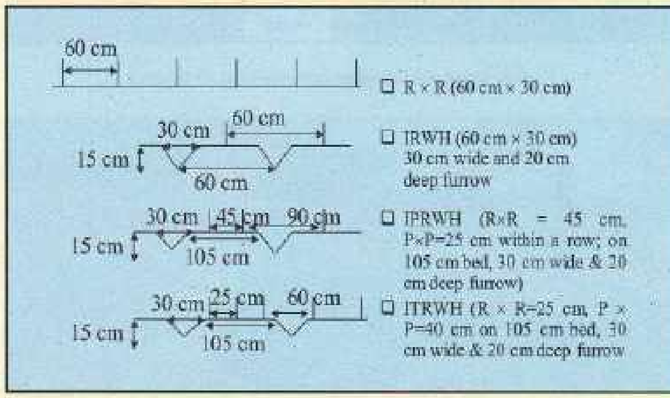

Fig. 2. Tractor operated water harvesting system

In the year 2003, 297 mm rainfall was received during July and August; thereafter the season was dry. Of 297 mm rainfall, 123 mm was received between August 26 to 30. Hence gap filling was done to attain complete plant population density in each treatment. Establishment percentage was computed around 15th August. Paired row and triplet row arrangement resulted in 85 and 81 per cent establishment while regular row plantation had only 58.5 per cent plant stand establishment

Fig. 3. Tractor operated furrow making and weed control

During 2004, furrows were opened between the row, row pairs, and triple row pairs before the onset of monsoon and around 30 days after first rainfall. A total of 237 mm rainfall was received during July and August and there was no rain after

September 6 at Jadan. The yield of dry leaves and biomass of middle row was low in triple row in comparison to regular row planting during 2004 due to competition for water.

Fig. 4. Inter row water harvesting in henna

Fig. 5. Henna without water harvesting

In-situ Water Harvesting

In conditions of dry land farming the solution to soil moisture problem lies in the storage of rainfall in the potential root zone by means of water harvesting (Singh, 1985). In 2003, henna planted in furrows/catchments provided 90 to 95 per cent establishment and the highest yield (194 kg ha^{-1}) was obtained with paired row followed by triple row and inter row water harvesting. In 2004, only 237 mm rainfall was received during cropping season that was inadequate to meet the water requirement of henna.

Integration of planting geometry into water harvesting resulted in 10.8 per cent increase over no harvesting treatment. The significance of compressed planting geometry into water harvesting (ITRWH) for minimizing evaporation losses through better canopy spread on planting zone had been reflected by obtaining 12.8 per cent higher yield over no water harvesting. Better planting configuration provided 17 per cent more yield than farmers practice (Rao *et al.*, 2003) and when it was integrated into water harvesting, 10.8 per cent additional yield was obtained. This integration of planting configuration into water harvesting brought about 28 per cent increase over farmers practice in arid fringes.

Conclusion

The use of the concepts of planting configuration as well as water harvesting together enhanced the yield of henna by 27 per cent over conventional farmers' practice. Water harvesting within row, row pairs or triple row pairs had not only conserved moisture but also minimized the infestation of weeds. Further, integration of balance nutrient, biofertilizers, IPM, crop residue, and gypsum, etc. into water harvesting needs to be investigated to develop complete package of practices for the henna growers in arid fringes.

References

Anonymous 2004. Http://www.Worldagroforestry.org/sites/treeDBS/Aft

Arnon, J. 1975. Physiological principals of dryland crop production. In U.S. Gupta (Ed.) *Physiological Aspects of Dryland Farming*, pp. 3-145, Oxford & IBH publishing Co., New Delhi.

Blum, A. 1970. Effect of plant density and growth duration on grain sorghum under limited water supply. *Agron. J.* 62: 333-336.

Burch, G.L., and G.G. Johns. 1978. *Aus. J. plant physiol.* 5: 859- 871.

Gode, P.K. 1999. History of henna (2000 BC to 1850 AD). *Asian Agricultural History* 3 (4): 235-244.

Haynes, J.L., C.H. Stringfield and W.A. Johnson. 1959. Effect of Corn planting pattern on yield, root extension and inter seeded cover crops. *Agron. J.* 51: 454- 456.

Jones, C.C. 2002. A short history of henna. *Copy right-Tap dancing lizard, library of congress.* pp. 1-5.

Koeppe, C.E., and G.C. Long 1958. *Weather and climate*. McGraw-Hill Book Co., New York.

Mukammal, E.I. and J.P. Bruce. 1960. Evaporation measurement by pan and atmometer. *International union of Geology and Geophysics, Association of Scientific hydrology,* No. 53: 408-420.

Rao, S.S., P.K. Roy, and P.L. Regar 2003. Effect of crop geometry and nitrogen on henna (*Lawsonia inermis* L.) leaf production in arid fringes. *Indian J. agric. Sci.* 13 (5): 283-285.

Shankarnarayana, K.A., and S.D. Singh. 1985. Transfer of technology to farmers involved in desert agriculture. *Farm bulletin-1*, CAZRI, pp. 15.

Singh, S. D. 1977. Optimum utilization of limited water supply. In: *Desertification and its control*, CAZRI, Jodhpur, pp. 237-255.

Singh, S.D. 1985. Potential of water harvesting in dry regions. *Annals of Arid Zone* 24: 9-20.

Singh, Y.V. and A. Saxena. 1998. Management of limited water resources for crop production. In: *Fifty Years of Arid Zone Research in India*, A.S. Faroda and Manjit Singh (Eds.), CAZRI, Jodhpur, pp. 189- 213.

Tomar, P.S. and S.L. Saini. 1979. Crop geometry and intercropping in rainfed pearlmillet. *Indian J. of agric. Sci.* 49: 627- 633.

Vyas, S.P. 2005. The performance of *Lawsonia inermis* L. in arid part of Gujarat *Indian J. Soil* (in press).

Henna- Legume Intercropping System for Sustainability in Arid and Semi-arid Region

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Growing of crops in mixed stands is regarded as more productive then growing them separately for better use of land and to avoid the risk of crop failure due to uncertain climatic conditions (Andrew and Kassam, 1976). In arid fringes of Rajasthan in Pali district, henna replaced traditional cropping system in last few decades owing to higher price for its dry leaves. Henna crop proved highly remunerative cash crop for the farmers having large holdings. Farmers belonging to small and marginal categories unable to bear establishment cost of henna due to lack of financial resources are still cultivating traditional crops in mixed cropping system during *kharif* season. Crops often fail due to recurring droughts; it is therefore, difficult for small and marginal farmers to earn their livelihood under such hostile environmental conditions. Henna being able to produce even with low rainfall (Rao *et al.*, 2003), may prove useful for intercropping system with traditional legume crops. The intercropping of legumes with cereals has been proved energy efficient technology for sustainability (Papendick *et al.*, 1976).

In this chapter, emphasis is given on cultural factors as choice of compatible components of crops with diverse morphology, crop geometry and density, relative time of sowing of component crops and competitive relations.

Background to Intercropping Systems

Growing of two or more crop species simultaneously in the same field during growing season is called intercropping. Common characteristics of different forms of intercropping are that they have the effect of intensifying crop production and exploiting more efficiently environment with limiting or potentially limiting growth resources (Papendick *et al.*,1976, Trenbath, 1982).

Andrews and Kassam (1976) identified four main types of intercropping

- Mixed intercropping : Growing component crops simultaneously with no distinct row arrangement; this is commonly used in labour intensive subsistence farming.
- Row intercropping : Growing component crops simultaneously in different rows; this is used in mechanized agriculture and in present research on intercropping, because it permits crop specific operations
- Strip cropping : Growing component crops simultaneously in different strips to permit the independent cultivation of each crop
- Relay intercropping : Growing component crops in relay, so that growth cycles overlap.

Crop Combination a Factor for Intercropping

Henna is a perennial shrub with deep rooting system generally planted in 30 cm apart rows in arid fringes of western Rajasthan. It attains a height of 65 to 85 cm and had a spread of 60 cm upon full growth. Once planted, crop continues to yield for 15-20 years. Cutting is done from the base of crop in the last week of September to first fortnight of October. Since it is rainfed, the farmers take one crop during July to September. The first approach mentioned above doesn't suit to henna crop while remaining three suits well. The growth of henna subsides due to low temperature during winter and thus there is scope to raise additional crop under conserved moisture (taramira, mustard, wheat and gram) i.e. relay cropping, provided it rains in the end of September. Such situation prevails once in five years, hence very little scope of adopting this approach in this region.

Alley cropping with henna (henna as alley) and component crops as intercropping may prove an economic alternative to the farmers in the region. The arid and semi-arid areas at the fringes of the Thar desert has the typical summer rainfall climatic conditions where monsoon rains are confined from mid-June to September end. The rainfall ranges between 300-600 mm. Since crop has short stature and completes its life cycle between July to September, short statured and short duration legumes have the scope of intercropping with henna. Pearl millet, sesame or sorghum are not advised as they have more height than henna and may suppress henna for light interception.

Indices for Evaluating Productivity and Efficiency

Willey (1985) suggested different indices to evaluate productivity and efficiency per unit area of land of cereal-legume intercrop systems. These include comparisons of absolute yield, caloric equivalent, and in economic terms, gross returns from intercrops and sole crops. In henna dry leaves are major component for marketing, hence, the yields of component crops are to be transformed into relative henna value.

Relative Yield Total : The mixture yield of a component crop expressed as a proportion of its yield as a sole crop from the same replacement series is the relative yield of the crop (Van den Bergh, 1968). The sum of the relative yields of component crops is called Relative Yield Total and is denoted by RYT. When the RYT is equal to or less than 1, there is no advantage to intercropping.

Calculation of RYT is originally based on the replacement series in competition studies, where proportions of the components in binary mixtures are varied but overall crop densities remain constant. The same calculation can in fact be applied to any density situation in intercropping. However, Mead and Riley (1981) have argued against its use because the objectives of intercropping are essentially agronomic, that is to find the best ways of growing crops together.

Land Equivalent Ratio : Willey and Osiru (1972) proposed the concept of the Land Equivalent Ratio (LER) as an index of combined yield for evaluating the effectiveness of all forms of intercropping. LER is defined as the total land area required under sole cropping to give the yields obtained in the intercropping mixture. It is expressed as:

$$\text{LER} = \left(\frac{Y_{ij}}{Y_{ii}}\right) + \left(\frac{Y_{ji}}{Y_{jj}}\right)$$

Where, Y is the yield per unit area, Y_{ii} and Y_{jj} are sole crop yields of the component, $_i$ and $_j$ and Y_{ij} and Y_{ji} are intercrop yields (Mead and Willey, 1981). The partial LER values L_i and L_j represent the ratio of the yields of crops $_i$ and $_j$ when grown as intercrops, relative to sole crops. Thus

$$L_i = \left(\frac{Y_{ij}}{Y_{ii}}\right) \quad \text{and } L_j = \left(\frac{Y_{ji}}{Y_{jj}}\right)$$

LER is the sum of the two partial land equivalent ratios :

$$LER = L_i + L_j$$

When LER = 1, there is no advantages to inter cropping in comparison with sole cropping. When LER >1, a large area of land is needed to produce the same yield of sole crop of each component than with an intercropping mixture. For example, when LER = 1.25, 25 per cent more land is needed to produce the same yield form the components as sole crop.

Area Time Equivalent Ratio: Hiebsch (1980) as a modification to LER proposed The Area Time Equivalent Ratio (ATER). This takes into account the duration of the crop i.e. the time it occupies from planting to harvesting; it also permits evaluation of crops on a yield-per-day basis. It does not appear to have been adopted widely. It is calculated as

$$ATER = \left(L_i t_i + L_j t_j\right) / T$$

Where L_i and L_j are relative yields or partial LERs of component crops $_i$ and $_j$, t_i and t_j are the durations (days) for crops $_i$ and $_j$, and T is the duration (days) of the whole intercrop.

Staple Land Equivalent Ratio: Here the objective is to produce a fixed yield of one-component (staple) crops usually cereal, and some yield of the legume. Reddy and Chetty (1984) proposed the concept of Staple Land Equivalent Ratio (SLER) as on extension of the LER. It is estimated as:

$$SLER = \left(\frac{Y_i}{Y_{ii}}\right) + P_{ij}\left(\frac{Y_{ji}}{Y_{jj}}\right)$$

Where Y_i / Y_{ii} is "The desired standardized yield" of staple $_i$, P_{ij} is the proportion of land devoted to intercropping, and Y_{ji} / Y_{jj} is the relative yield of crop $_j$. It is peculiar to Indian condition.

Comparison of RYT, LER, ATER and SLER : RYT is based on replacement series, while ATER and SLER restricted to specific intercrop situation. ATER is only appropriate in system with component crops of contrasting maturities. When components are of similar growth durations, ATER values are similar to RYT and LER. Among these four, LER is considered to be most appropriate general functions to determine the efficiency of the intercropping with legumes. When differences between growth duration of component are substantial, time becomes an important element and ATER is considered to be more appropriate index of efficiency of the system.

Competitive Relations Between Component Crops

Component crops compete for growth factors when grown on same piece of land. Production efficiency could be improved by minimizing interspecific competition between the component crops for growth limiting factors. It is thus desirable to grow crops of contrasting maturities so that they may complement each other rather competing for the same resources at the same time. In henna-legume intercrop systems, henna may act as dominant and legume as dominated component. So intercropping of legumes with henna (as dominant crop) needs proper attention. It would be more appropriate either to select short duration legume (maturing earlier than henna) or select long duration legume (maturing later than henna). The height should not be more than henna crop and their canopy should be erect. Time of sowing factor is to be considered carefully. In general yield of intercrop is low than sole crop because of low population and competition for water, nutrients and light on same piece of land. Intercropping has one advantage that either both components provide yield or one component may yield while other may fail under aberrant weather condition. So farmer is able to harvest some produce. It also improves soil health.

Factors Affecting Intercropping System

Light : the rate of dry matter production in crops depends on the efficiency of interception of photosynthetic active radiation (PAR) (Biscoe and Gallagher, 1977). The amount of light intercepted by the component crops in an intercrop system depends on the geometry of the crops and foliage architecture (Trenbath, 1982). Generally taller crops and high densities may cause reduced growth and yield of companion legume. The higher overall productivity of intercrop system compared to sole crop may be attributed to better utilization by a crop canopy composed of plants with different foliage distributions (Willey and Roberts, 1976). Intercropping system allows better spread of light over greater leaf area during early stage than sole crop.

Water : Water is the most important soil factor in arid/semi-arid and sub tropical regions for any intercropping system because inadequate rainfall may frequently limit crop production (Baker and Norman, 1975). Depth of rooting, lateral root spread and root-density are factors that affect competition for water between component crops (Babalola, 1980; Haynes, 1980).

Nutrients : Balance nutrition of component crop is the most important factor. However, farmers do not apply any fertilizer to henna and legume in this region. But these crops may compete for N, P and K and other micronutrients. Since henna is perennial crop it may exhaust these nutrients in the long run. So balanced application of nutrients is essential to attain the sustainable production of any intercropping system.

Agronomic Factors Influencing Productivity of Intercropping

Crop density, plant spacing and arrangement, relative times of sowing of component crops are some of the factors, which influence the efficiency of intercrop systems.

Component crop density : Lakhani (1976) reported that the overall densities and the relative proportions of component crops are important in determining yields and production efficiency of intercropping system. In henna one has to carefully design replacement series or proportions and plant densities to obtain the sustainable production of henna and legume crops.

Plant arrangement and spacing : Row arrangements, in contrast to arrangement of component crops within rows, improve the amount of light transmitted to the lower legume canopy. Such arrangements are required to enhance legume yields and efficiency of any intercrop system. In henna such studies have not been conducted anywhere in the world. Henna crop attains a height of 65-85 cm at peak growth stage and canopy spread is around 60 cm in general towards rows and 30 cm within rows. However, within rows overlapping is observed. In studies conducted by Rao *et al.* (2003), it had been observed that 60 cm x 30 cm spacing provided 17 per cent more yield than regular row spacing (30 cm x 30 cm). So to provide sufficient light to component legume crop, proper planting arrangement needs standardization. Considering the 60 cm circular spread by henna plant different planting arrangement designs have been worked out and following systems were incorporated in our study to compare the performance and compatibility of henna-legume intercropping system for sustainable production at the fields of small and marginal farmers in arid fringes.

- Intercropping system in 1:1 proportion : In this system one row of henna (space at 1.2 m) was alternated with one row of legume and each crop component was spaced at 60 cm from each other. In this system the plant population proportion in per unit area land would be 50:50 (Fig. 1).
- Intercrop system in 1:2 proportions : Two rows of legumes at 40 cm distance were planted in between two rows of henna (spaced at 1.20 meter). In this case, population of legume would be twice to that of henna on same piece of land (Fig. 2).

Fig. 1. Henna legume intercropping in 1:1 ratio

Fig. 2. Henna legume intercropping in 1:2 ratio

- Intercrop system in 1:3 proportions : In this system three rows of legumes in between two rows of henna (1.20 meter) are incorporated. Legume populations would be thrice to that of henna (Fig. 3).

Fig. 3. Henna legume intercropping in 1:3 ratio

- Intercrop system 1:5 proportions : growing legume components with henna in 5:1 proportion, where in henna is spaced at 3.6 meter and five rows of legume planted in three meter space. The proportion of legume to henna would be 83:17 in this system. Each row whether of henna or legume are spaced at 60 cm from the other one.

- Strip-crop system : A 2.4-meter wide strip of henna was alternated with 2.4-meter wide strip of legume (Fig. 4). In this system population percentage proportion would be in a ratio of 50:50. Selection of 2.4-meter wide strip was considered on the criteria that sowing of legume and interculturing between rows is possible with tractor-operated equipments. Both the components are spaced at 60 cm apart so as to facilitate interculture with tractor to control weeds and conserve soil moisture. This system may have an advantage over replacement series described above because crops may not compete for light interception as both are raised on separate strips. Secondly both crops may have different zone for soil moisture and nutrient extraction. However, the advantage of legume in fixing nitrogen may not be there as is with replacement series of inter-crop system described above.

Fig. 4. Henna legume strip cropping

- Alley crop system in 2:4 proportions: In this system two rows of henna were planted in isosceles configuration in 60 cm rows at 3-meter distance. Four rows of legume were arranged in the open strip. Legume and henna would be in the proportion of 66:33 in this system. Henna would be maintained in the form of hedge from third year onwards after plantation.

- Alley crop system in 2:10 proportion: Paired row of henna in isosceles configuration at 60 cm are planted at 6-meter distance. The 6-meter space was used to plant 10 rows of legume component. Population of legume and henna would be in 10:2 proportions in this system, which means population of legume and henna would be in 83:17 proportions.

Henna seedlings were transplanted with onset of effective rains in July 2003. A total of 258.5 mm rainfall was received from July to August 28 in 2003. Since the year was the establishing year, no intercrop was planted. In second year the intercrop component i.e. legume could be planted on August 4, 2004 after receiving effective rain showers. The plot size was kept 14.4 m x 10 m and experiment was laid out in a randomized block design with four replications. There were two sole crops of henna and legume components. In legume component short duration cultivars of moong bean RMG-268 and clusterbean RGC-936 were included in the study. There was no rainfall in July and September. First pre-monsoon shower of 33 mm was received on June 14. There was very little rains from June 15 to July 29. On July 30, 2004 good rains were received which continued till 25th August 2004. Thereafter, it was totally dry till harvesting. Thus henna received 309.4 mm rainfall whereas legume component received only 226 mm rainfall from July 30 to August 25. As a result legume component was severely affected with moisture stress. Moong bean failed to produce any grain yield while clusterbean could produce some yield.

Relative Time for Sowing of Component Crops

The relative time of sowing of component crops may be important management variable for any intercrop system. Andrews (1972) pointed out that differential sowing improves productivity and minimizes competition for growth limiting factors in intercropping. This may be effective in areas having long duration rainy season where long duration intercrop like pigeon pea or castor may take the advantage of rainwater after the harvest of dominant crop. In areas, particularly the arid fringes that generally receive rains in between 300-550 mm, differential time of sowing may not be effective preposition. In henna-legume intercrop system, henna is permanent and perennial component, the sowing of legume may prove deciding factor. As the rainfall is for very short period in arid and semi-arid fringes of the Thar Desert, legume component may have to compete for same available water supply in the season. Since the growth of henna after first rainfall is slow due to time taken for sprouting of culms, the sowing of legume crop component can be delayed up to 20th July at the most. Further delay in sowing may be affected by early withdrawal of monsoon like the year 2004.

The Role of Legumes in Intercrop System

Generally farmers grow henna without any kind of fertilizer application in the region. Since henna is a perennial component it may deplete essential nutrient from the soil profile. Legume-component may replenish nitrogen requirement to some extent and its roots biomass may also replenish some other nutrients. There are three main sources of nitrogen supply to crop: these are N fixed by the legume component from atmosphere, from fertilizer and from soil. Study conducted at CAZRI revealed that moong bean and clusterbean contribute about 290 and 300 g g^{-1} of soil in 0-15 cm soil depth respectively by fixing atmospheric nitrogen (Kumar *et al.*, 1998). The resultant change in soil N after the harvest and return of residues may be calculated as:

N = N (residues) - N ((uptake from soil)

Legume based intercropping with henna would be definitely help in N budgeting and improving the production of henna-legume intercrop system in the region.

Initial Achievements

Prevailing drought conditions, particularly in legume component, affected the production of legumes during 2004. The results obtained in respect of henna-clusterbean intercrop system are described below.

Clusterbean could produce some grain yield, which revealed that clusterbean has the ability to produce grain when compared to moong bean, however the yield levels were quite low. About 226 mm rainfall received between July 30 to August 25 was not sufficient to meet the water requirement of the crop as there was severe moisture stress during September. Pure henna produced highest yield (517 kg ha^{-1}) followed by strip cropping (411 kg ha^{-1}). Economic analysis also indicated that sole henna crop gave a net profit of Rs. 5,142 ha^{-1} followed by strip cropping (Rs. 2,922 ha^{-1}). The overall picture will emerge after 2-3 years when henna will attain peak growth.

Future Research Thrusts

Intercropping of henna with legumes may prove advantageous preposition for small and marginal farmers dwelling in arid and semi-arid fringes of the Thar Desert. Some areas for future research are as follows :

- Optimisation of plant density and row arrangement in henna legume intercrop system.
- Morphological compatibility of different genotypes of legume with henna.
- The pathways of N losses from henna-legume intercrop system to maximize utilization of N-nutrient.
- The application of low rates of N and P in order to encourage N_2 fixation of intercrop legume and provide better root biomass of legume.
- The amounts of fixed N in below ground parts of component crops to permit accurate estimates of N balances in henna-legume intercropping systems.
- Quantification of competition for light, moisture and nutrient under different intercropping systems and selection of compatible legume component with henna.

Results from study will definitely encourage henna cultivation along with legume so as farmers may obtain food grains for their daily consumption and extra income from henna that is generally sold at the rate of Rs. 2,200/- per 100 kg in the region. A good intercrop system may provide 800-1000 kg dry leaves of henna (about 50% of main/sole crop of henna) after three years of plantation, which may provide around Rs. 17,600 - 22,000 (additional total income) to the farmers depending upon market price.

References

Andrews, D.J. 1972. *Exp. Agric.* 8: 139-150.

Andrews, D.J., and A.H. Kassam. 1976. In "Multiple cropping" (R.I. Papendick, P.A. Sanchez, and F.B. Triplett, Eds.), pp 1-10, Spec. Pub. No. 27, *Am. Soc. of Agron.*, Madison, Wisconsin.

Babalola, O. 1980. *Plant soil*, 56: 59-69.

Baker, E.F.I. and D.W. Norman 1975. Proc. *Cropping sys. Workshop*, pp. 334- 361, IRRI, Los Banos, Philippines.

Biscoe, P.V., and J.N. Gallagher 1977. In "*Environmental effects on crop physiology*" (J.J. Landsberg and C. V. Cutting, Eds.) p. 75-100. Academic press, New York.

Haynes, R.J. 1980. *Adv. Agron.* 33: 227-261.

Hiebsch, C. K. 1980. Principles of intercropping: Effects of nitrogen fertillization, plant population and crop duration on equivalency ratios in intercrop verses monoculture comparisons. *Ph. D. Thesis, North Carolina State Univ., Raleigh.*

Kumar, P., Y.V. Singh, S. Lodha and R.K. Agarwal. 1998. Efficient management of resources for sustainable crop production in arid region. *CAZRI, Research bulletin*, pp. 1-72.

Lakhani, D.A. 1976. A crop physiological study of mixtures of sunflower and fodder radish. *Ph. D. Thesis, Univ. of Reading.*

Mead, R. and J. Riley 1981. *J. R. Statist. Soc. Ser. A.* 144: 462-509.

Papendick, R.I., P.A. Sanchez and G.B. Triplett. 1976. "Multiple cropping" p. 378, Spec. Pub. No. 27. *Am. Soc. of Agron.* Madison, Wisconsin.

Rao, S.S., P.K. Roy, and P.L. Regar 2003. Effect of crop geometry and nitrogen on henna (*Lawsonia inermis* L.) leaf production in arid fringes, *Indi. J. Agric. Sci.* 13 (5): 283-285.

Reddy, M.N. and C.K.R. Chetty 1984. *Exp. Agric.* 20: 171-177.

Trenbath, B.R. 1982. Proc. Front. Res. Agric. Indian Statist. Inst. *Golden Jubilee Int. Conf., Calcutta*, pp. 265- 286.

Van den Bergh, J.P. 1968. *Versl. Landbouwkd.* Onderz. 714, 1-71.

Willey, R.W. 1985. *Exp. Agric.* 21: 119-133.

Willey, R.W., and D.S.O. Osiru. 1972. *J. Agric. Sci.* 79: 517-529.

Willey, R.W. and E.H. Roberts. 1976. *Int. Solar Energy Soc. Conf. Univ. Reading.*

Plant Protection in Henna and Henna for Pest and Disease Management

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Until recently henna crop in the arid regions was considered to be generally free from the attack of insect pests except termites. With the increase in the area over the years since its introduction in the region, there have been increasing instances of attack by various pests in recent years. The castor semilooper, *Achaea janata* Linnaeus causing heavy defoliation is on its way to establish as a major pest on henna, although its appearance so far has been rather sporadic (Fig. 1). In our studies initiated few years ago it was first observed damaging henna in 1999, the next year its intensity increased and the following season during August-September in 2001 it acquired epidemic form in areas around Sojat. The severity of attack varied in different henna cultivating fields, the larval population per bush ranged from 3 to 27 in the locations surveyed. The pest did not appear in same seriousness in subsequent years. However, with the expansion of castor cultivation in the arid regions, this insect may prove to be a major pest on henna during coming years especially during good rainfall years. The cultivators were accustomed not to use any pesticides on henna foliage, but the attack of the semilooper enjoined many to adopt protective measures, adding to the cost of cultivation or reduced remuneration on yield. In laboratory trials, quinalphos and fenitrothion proved to be effective insecticide against the semilooper (Singh, 1982). Bt based formulations may be used as well.

Fig. 1. Semilooper damaging henna crop

Termite attack in henna, which is mostly a rainfed crop, accentuates during water stress conditions. The damage is more during the initial establishment phase, when a good number of saplings succumb to the termite injury. The destroyed saplings are often replaced in the following season. When the damage occurs in established stage, often no replanting is done. The current practice is not to adopt pre-planting soil application of any pesticides for the prevention of termites. Because of close planting currently in practice, spot treatment is inconvenient. It would be wise to treat soil with dust formulation of insecticides like endosulfan before planting to protect the plants in initial stage. Biological control agents like *Metarrhizium anisopliae* and *Beauveria* sp may be used against the termites.

The crop was also observed infested by the mealy bug *Ferrisia virgata* Cockerel, devitalizing the plants at main stem and branches. Verma (2003) reported bug population up to 20 per plant. At many places the blister beetles (*Mylabris* spp.) were observed damaging inflorescence in September. In the new leaves after pruning of henna raised as hedge, unidentified aphids were observed at some locations in Rajasthan (Fig. 2). In northeast India, infestation of the aphid *Tinocallis kahawaluokalani* (Kirkaldy) has been reported (Agarwala *et al.*, 1989). Nagaraja *et al.* (1994) reported infestation by *Helopeltis antonii*, a mirid bug on henna plants serving as hedge. In China, henna has been reported infested by the white fly *Bemisia afer* (Fu *et al.*, 1998). In Iraq, henna has been reported hosts of *Meloidogyne javanica*, the root knot nematode (Stephan, 1988). Detailed studies on the insects associated with henna and their management in the arid and semi-arid environment is need of the hour.

Fig. 2. Aphids on henna leaves

There are no major diseases associated with henna in the arid regions at present. In areas around Sojat, leaves were observed to exhibit small brownish spots, the cause of which is unknown. In the Philippines, leaf spot on henna have been reported to be caused by *Cercospora* sp. (Quiniones and Dayan, 1981). Narain (1983) reported it to be a host for *Alternaria tenuissima*. Bagyanarayana *et al.* (1988) described *Ovulariopsis lawsoniae* from Hyderabad. Firdousi *et al.* (1990) reported occurrence of *Alternaria alternata* on living leaves in Karnataka. Sharma and Singh (1992) recovered *Sporidesmimum adscendens* from dead stems of henna. Henna is also known to be a symptomless carrier for *Fusarium* spp, which cause Bayoud disease (vascular wilt) of date palms in the Zagora region of Morocco, but it did not seem to favour the multiplication and spread of *Fusarium oxysporum* f.sp. *albedinis* in soil (Tantaoui, 1993). Teotia (1995) reported the occurrence of *Botryodiploidea theobromae* on its leaves in West Bengal. From China Song and Li (2002) reported occurrence of *Asterina lawsoniicola* sp. nov. parasitic on this crop.

Henna for Pest and Disease Management

Henna itself is being used for the management of insect pests and diseases caused by various pathogens like fungi, bacteria, viruses, nematodes, etc. Ali (1996) ascribed the antifungal, antibacterial, antiviral, immunoinhibitory, immunostimulatory, nematicidal and toxicological effects of henna to aliphatic constituents, triterpenoids, sterols, naphthoquinone derivatives, phenolic constituents, coumarins, xanthones and flavonoids found in this plant.

Dwivedi and Garg (1997) reported the ovicidal effect of henna leaf extract on the rice moth *Corcyra cephalonica*. Mathew *et al.* (1999) found that leaf extracts inhibited the reproductive ability of the cardamom aphid, Pentalonia *nigronervosa* f. *caladii* completely at 25 and 50 per cent concentration in small cardamom. Dwivedi and Kumari (2000) evaluated henna extract as repellent against *Callosobruchus chinensis* and found moderate activity. El-Basheir and Fouad (2002) have reported the effectiveness of henna in different combinations against the head lice *Pediculosis capitis* in Egypt. Singh and Sharma (2003) reported the effectiveness of seed coating of green gram (*Vigna radiata*) with henna oil in providing protection against pulse beetle *Callosobruchus chinensis*. In a similar study Singh and Yadav (2003) found that henna oil at 10 ml kg^{-1} seed was effective against *C. chinensis* in green gram beyond 150 days after treatment. The oil at 10 ml kg^{-1} seed was effective even after 9 months of treatment. Meena and Bhargava (2003) tested the efficacy of henna extract/oil in controlling *Corcyra cephalonica* infesting rice and found the fecundity, egg viability and longevity of both males and female *C. cephalonica* decreased with increasing concentrations of the extract and the oil.

Singh and Singh (2001) studied the molluscicidal properties of extracts of leaves, bark and seeds of henna against *Lymnaea acuminata* and *Indoplanorbis exustus* and found the seed extract to be the most toxic. Combinations of henna with *Cedrus deodora* or neem were more toxic than their individual components.

Whereas henna plants are reported to be a host for the nematode *Meloidogyne javanica*, a number of studies indicate the use of henna for suppression of the root knot nematodes. Kumari *et al.* (1987) reported that methanolic extracts of henna leaves at a dose of 4 mg ml^{-1} or at 1:5 dilution, caused high larval mortality in *M. javanica*, with oil extracted from the seeds also causing though lower mortality. The bark extracts of henna caused significant suppression of larval hatching in the nematode *M. incognita* (Rafiq *et al.*, 1991). The nematicidal potential of the henna plant against the root knot nematode *M. incognita* in tomato was studied by Korayem and Osman (1992), who found that henna reduced tomato root gall numbers, number of the egg-laying females and rate of the nematode reproduction, when tomato and henna were grown together. Also, the same reduction in these nematode biological processes was found when tomato plants were grown in soil containing root exudates of henna but in lesser amounts. Jain and Trivedi (1997) also studied the nematicidal activity of henna against root-knot nematode, *Meloidogyne incognita* infecting chickpea and found that its leaf powder as organic amendments caused a marked decline in number of root galls, eggs per egg-mass and final nematode populations, indicating a reduction in severity of disease. Further, the average root and shoot length, dry and fresh weight of the crop tended to increase in amended soil. Plant extracts from henna have been successfully used as dyes for differentiating between inactive living and dead nematodes in laboratory tests (Gaur and Chandel, 1998). Javed *et al.* (2001) reported inhibition of eggs and juvenile mortality of *M. javanica* in tomato following treatment with henna. Dama (2002) studied the effect of naturally occurring napthoquinones on root-knot nematode *M. javanica* and found plumbagin, juglone and lawsone to be nematicidal.

The activity of henna leaf extract against *Cochliobolus miyabeanus* was tested by Natarajan and Lalithakumari (1987). The anti-fungal factor contained in the leaf was identified as 2-hydroxy-1, 4-naphthoquinone (lawsone). *In vivo*, spraying rice leaves with the extract gave better control than seed treatment. Its extract also exhibited fungistatic activity against *Rhizoctonia solani*, causal organism of sheath blight of rice (Ansari, 1995). Kurucheve *et al.* (1997) recorded complete inhibition of sclerotial growth of *Rhizoctonia solani*, the causal agent of sheath blight of paddy rice with the cold-water extracts of henna during in vitro testing for fungitoxicity. The plant extract maintained the fungitoxicity following thermal treatment at 70°C for 10 minutes. Bhadauria and Kumar (1999) reported the flavonoids from extracts of henna to exhibit the highest fungal growth inhibition of *Candida albicans*. Jayashree *et al.* (2000) reported henna extracts to be effective in inhibiting spore germination of the rice blast pathogen *Pyricularia oryzae*. Pandey *et al.* (2002) recorded 90% mycotoxicity of leaf extracts against *Helminthosoporium sativum* (*Cochliobolus sativus*).

Extract of henna was also found effective in checking fruit rot of lemon caused by *Colletotrichum gloeosporioides* (*Glomerella cingulata*) and *Botryodiplodia theobromae* where pre-inoculation treatments were more effective than post-inoculation (Babu and Reddy, 1986). The antifungal activity of henna has also been reported against *Pestalotiopsis mangiferae* causing leaf-spot disease in mangoes (Rai, 1996). Kurucheve and Padmavathi (1997, 1998) have reported the effectiveness of henna leaf extract against *Pythium aphanidermatum* causing damping off of chillies.

In the experiments with alcoholic and aqueous solutions of henna and lawsone, Millet-Clerc et al (1989) found that whereas the solutions had no antifungal activity against *Pityrosporum ovale*, lawsone showed fungistatic and fungicidal activity at one per cent w/v. Ghewande (1989) reported aqueous leaf extracts to be effective in controlling diseases of groundnut caused by *Phaeolsariopsis personata* (*Mycosphaerella berkeleyi*) and *Puccinia arachidis* with increase in yields. Bansal and Sobti (1990) also reported the effectiveness of henna extract against *Aspergillus flavus* in groundnut. Aqueous and ethanol leaf extract of henna at 25 per cent (w/v) concentration completely inhibited the conidial germination of *P. personata* causing late leaf spot of groundnut in Gujarat. El-Sayed and Badawey (1991) observed that powdered henna inhibited mycelial growth and delayed sporulation of *Aspergillus parasiticus* and also inhibited aflatoxin production by the fungus. Aqueous and ethanol leaf extracts were highly inhibitory to conidial germination up to one per cent concentration. Ethanolic extract up to 60°C was highly stable and retained its fungitoxic effects (Kishore et al., 2001). In Andhra Pradesh groundnut crop treated with henna extract contained late leaf spot disease (*M. berkeleyi*) progress up to 95 DAS. Pod yields in plots sprayed with henna extract was 20 per cent higherr than the control plots (Kishore *et al.*, 2002).

Extracts of *Lawsonia alba* (*L. inermis*) were found to exhibit high inhibitory effect on tobamoviruses on tobacco by Nagarajan *et al.* (1990) and Khan *et al.* (1991). Ethanolic extract of *Lawsonia inermis* showed selective antifungal activity against *Colletotrichum capsici*, *Fusarium pallidoroseum*, *Botryodiplodia theobromae*, *Alternaria alternata*, *Penicillium citrinum*, *Phomopsis caricae-papayae* and *Aspergillus niger* in Malayasia (Mohamed *et al.*, 1996). In the *in vitro* evaluation of botanicals for mycotoxic properties against *Alternaria alternata* causing brown spot disease of tobacco, Shenoi *et al.* (1999) found significant reduction in the radial growth of the fungus at 1:1 concentration of henna leaf extract.

In cotton, henna extract inhibited spore germination and mycelial growth of *Alternaria macrospora* and *Myrothecium roridum* during *in vitro* tests and also exhibited activity against *Xanthomonas campestris* pv. *malvacearum* (Bambewala *et al.*, 1995). In vivo tests showed that *Lawsonia alba* controlled myrothecium leaf spot on cotton plants. Henna extract also gave good control of *X. campestris* pv. *malvacearum*, corroborating the *in vitro* studies. Singh and Tripathi (1995) found in their studies that aqueous extract of henna leaves completely inhibited the mycelial growth of *F. oxysporum* f.sp. *lentis* causing wilt disease in lentil.

In experiments with French bean Ravi *et al.* (2000) observed that seed treatment + foliar spray of aqueous leaf extract of henna, as well as seed treatment alone, significantly improved the seedling emergence, reduced the *Colletotrichum lindemuthianum* disease incidence, increased the yield per plant and 100-seed weight. Further, the resulting seeds were found to be free from seed infection under blotter method. Seed treatment followed by foliar spray was more effective than seed treatment alone. In soybean, seed treatment + a foliar spray with henna leaf extract (1%) + alum (0.1%) proved effective against leaf anthracnose and pod blight incidence (Chandrasekharan *et al.*, 2000 a,b; Chandrasekaran and Rajappan, 2002).

Satish *et al.* (1999) while studying the antibacterial activity of plant extracts on phytopathogenic *Xanthomonas campestris* pathovars found that henna showed high antibacterial activity, based on the zone of inhibition in a diffusion assay. The naturally occurring naphthoquinones compounds from henna have been reported inhibiting the bacteria Escherichia coli, *Klebsiella pneumoniae*, *Campylobacter jejuni*, *Staphylococcus* sp., *Bacillus* sp., *Mycobacterium* sp., *Corynebacterium diphtheriae* and *fungi Aspergillus* sp., *Helminthosporium* sp. and yeast *Candida albicans* (Dama *et al.*, 1998).

On the other hand, the leaves of henna have also been reported exhibiting synergistic effect on the beneficial bacterium *Bacillus thuringiensis* var. *tenebrionis* against *Leptinotarsa decemlineata* in Iran (Kahrizeh *et al.*, 2003). The effectiveness of Bt under field conditions is reduced because sunlight inactivates its spores and crystals. Therefore the formulation must contain ultraviolet protectants. Zareie *et al.* (2003) tried mixtures of molasses and henna for improving *B. thuringiensis* residual activity against *Galleria mellonella* larvae and found the treatments to minimize loss of activity of Bt.

Henna may play useful role in public hygiene too. While screening plant species for inhibition of bacterial population of raw water, Kumar and Gopal (1999) found the highest effectiveness of henna in reducing the bacterial population of raw drinking water.

References

Agarwala, B.K.; Mahapatra, S.K. and Ghosh, A.K. 1989. Description of sexual morphs of Tinocallis kahawaluokalani (Kirkaldy) (Homoptera: Aphididae) from India. *Entomon* 14 (3-4): 273-274.

Ali, Mohammad. 1996. Chemical and medicinal evaluation of Lawsonia inermis (henna). *Hamdard Medicus* 39 (4): 43-48.

Ansari, M.M. 1995. Control of sheath blight of rice by plant extracts. Indian *Phytopathology* 48 (3): 268-270.

Babu, K.J. and Reddy, S.M. 1986. Efficacy of some indigenous plant extracts in the control of lemon-rot by two pathogenic fungi. *Science-Letters -National Academy of Sciences, India* 9 (5): 133-134.

Bagyanarayana, G.; Braun, U. and Hosagoudar, V.B. 1988. Ovulariopsis lawsoniae spec. nov. *Mycotaxon* 32: 457-459.

Bambawale, O.M.; Mohan, P; and Chakraborty, M. 1995. Efficacy of some medicinal plants against cotton pathogens. *Advances in Plant Sciences* 8 (2): 224-229.

Bansal, R.K. and Sobti, A.K. 1990. An economic remedy for the control of two species of Aspergillus on groundnut. *Indian Phytopathology* 43(3): 451-452.

Bhadauria, S and Kumar, P. 1999. Effect of plant extracts of medicinal plants against Candida albicans. *Flora and Fauna* (Jhansi) 5 (2): 95-96.

Chandrasekaran, A; Narasimhan, V. and Rajappan, K. 2000a. Integrated management of anthracnose and pod blight of soybean. *Annals of Plant Protection Sciences* 8 (2): 163-165.

Chandrasekaran, A; Narasimhan,V. and Rajappan, K. 2000b. Effect of plant extracts, antagonists and chemicals on seedling vigour and anthracnose disease of soybean. *International Journal of Tropical Plant Diseases* 18 (1-2): 141-146.

Chandrasekaran,A. and Rajappan, K. 2002. Effect of plant extracts, antagonists and chemicals (individual and combined) on foliar anthracnose and pod blight of soybean. *Journal of Mycology and Plant Pathology* 32 (1): 25-27.

Dama, L.B. 2002. Effect of naturally occurring napthoquinones on root-knot nematode Meloidogyne javanica. *Indian Phytopathology* 55 (1): 67-69.

Dama, L.B.; Poul, B.N. and Jadhav, B.V. 1998. Antimicrobial activity of naptroquinonic compounds. *Journal of Ecotoxicology and Environmental Monitoring* 8 (3-4): 213-215.

Dwivedi, S.C. and Garg, S. 1997. Screening of plant extracts for ovicidal effect on the rice moth, Corcyra cephalonica (Stainton). *Pest Management and Economic Zoology* 5 (1): 53-55.

Dwivedi, S.C. and Kumari, A. 2000. Evaluation of some plant extracts as repellent against Callosobruchus chinensis (Linn.). *International Journal of Tropical Agriculture* 18 (2): 181-183.

El-Basheir, Z.M. and Fouad, M.A.H. 2002. A preliminary pilot survey on head lice, Pediculosis in Sharkia Governorate and treatment of lice with natural plant extracts. *Journal of the Egyptian Society of Parasitology* 32 (3): 725-736.

El-Sayed, A.M.A.A. and Badawey, A. 1991. Inhibitory effect of henna (Lawsonia inermis leaves) and carrot root on aflatoxin production by Aspergillus parasiticus. *Mycotoxin Research* 7 (2): 61-68.

Firdousi, S.A.; Rai, A.N. and Vyas, KM. 1990. New host records from India. *Indian Phytopathology* 43 (2): 238.

Fu, J.W.; Huang, J.A. and Zhen, Q.H. 1998. Occurrence and damage caused by Bemisia afer (Homoptera: Aleyrodidae) on soybean in Fuzhou. *Wuyi Science Journal* 14: 68-72.

Gaur, H.S. and Chandel, S.T. 1998. Indigenous non-toxic herbal stains for differentiation of live and dead nematodes. *Annals of Plant Protection Sciences* 6 (2): 216-219.

Ghewande, M.P. 1989. Management of foliar diseases of groundnut (Arachis hypogaea) using plant extracts. *Indian Journal of Agricultural Sciences* 59(2): 133-134.

Jain, Charu and Trivedi, P.C. 1997. Nematicidal activity of certain plants against root-knot nematode, Meloidogyne incognita infecting chickpea, Cicer arietinum. *Annals of Plant Protection Sciences* 5 (2): 171-174.

Javed, N.; Qureshi, F.F.; Ahmad, R. and Ashfaq, M. 2001. Evaluation of products of bionature against root-knot nematodes Meloidogyne javanica (Treub) on tomato. *Pakistan Journal of Phytopathology* 13 (2): 155-159.

Jayashree, K; Rajeswari, E. and Thiribhuvanamala, G. 2000. Effect of plant extracts on the spore germination of rice blast pathogen. *Madras Agricultural Journal* 87 (1-3): 144-146.

Kahrizeh, A.G.; Safaralizadeh, M.H. and Pourmirza, A.A. 2003. The effect of Bacillus thuringiensis var. tenebrionis on Colorado potato beetle larvae, Leptinotarsa decemlineata (Say) (Coleoptera: Chrysomelidae) and role of henna as a synergist in increasing its efficiency. *Iranian Journal of Agricultural Sciences* 34 (3): 539-547.

Khan, M.M.A.A.; Jain, D.C.; Bhakuni, R.S.; Mohd Zaim and Thakur, R.S. 1991. Occurrence of some antiviral sterols in Artemisia annua. *Plant Science Limerick* 75 (2): 161-165.

Kishore, G.K.; Pande, S. and Rao, J.N. 2001. Control of late leaf spot of groundnut (Arachis hypogaea) by extracts from non-host plant species. *Plant Pathology Journal* 17 (5): 264-270.

Kishore, G.K. Pande, S. and Rao, J.N. 2002. Field evaluation of plant extracts for the control of late leaf spot in groundnut. *International Arachis Newsletter* 22: 46-48.

Korayem, A.M. and Osman, H.A. 1992. Nematicidal potential of the henna plant Lawsonia inermis against the root knot nematode Meloidogyne incognita. *Anzeiger fur Schadlingskunde, Pflanzenschutz, Umweltschutz* 65 (1): 14-16.

Kumar, S. and Gopal, K. 1999. Screening of plant species for inhibition of bacterial population of raw water. Journal of Environmental Science and Health Part A: *Toxic Hazardous Substances and Environmental Engineering* 34 (4): 975-987.

Kumari, R.; Verma, K.K.; Dhindsa, K.S. and Bhatti, D.S. 1987. Screening of aerial parts of Datura, Ipomoea, Tagetes and Lawsonia for their nematicidal activity on Meloidogyne javanica. *Agricultural Science Digest* 7 (4): 213-216.

Kurucheve, V.; Ezhilan, J.G. and Jayaraj, J. 1997. Screening of higher plants for fungitoxicity against Rhizoctonia solani in vitro. *Indian Phytopathology* 50 (2): 235-241.

Kurucheve, V. and Padmavathi, R. 1997. Fungitoxicity of selected plant products against Pythium aphanidermatum. *Indian Phytopathology* 50 (4): 529-535.

Kurucheve, V. and Padmavathi, R. 1998. Management of damping-off of chillies with plant products. *Indian Phytopathology* 51 (4): 379-381.

Mathew, M.J.; Venugopal, M.N. and Saju, K.A. 1999. Effect of plant extracts on cardamom aphid on small cardamom. *Indian Journal of Virology* 15 (2): 111-114.

Meena, B.L. and Bhargava, M.C. 2003. Effect of plant products on reproductive potential of Corcyra cephalonica Stainton (Lepidoptera: Pyralidae). *Annals of Plant Protection Sciences* 11 (2): 196-200.

Millet-Clerc, J.; Michel, D.; Levy, F and Chaumont, J.P. 1989. In vitro antifungal activity of henna and lawsone against Pityrosporum ovale. *Plantes Medicinales et Phytotherapie* 23 (3): 162-168.

Mohamed, S.; Saka, S and Muid, S. 1996. Antimycotic screening of 58 Malaysian plants against plant pathogens. *Pesticide Science* 47 (3): 259-264.

Nagaraja, K.V.; Gowda, P.S.B.; Kurup, V.V.K. and John, J.N. 1994. Biochemical changes in cashew in relation to infestation by tea mosquito bug. *Plant Physiology and Biochemistry* 21 (2): 91-97.

Nagarajan, K.; Murthy, N.S. and Reddy, T.S.N. 1990. Utilization of botanicals possessing antiviral principle against tobacco mosaic virus. Botanical pesticides in integrated pest management: *Proceedings of National Symposium* held on January 21-22, 1990 at Central Tobacco Research Institute, Rajahmundry : 407-412.

Narain, U. 1983. Some new host records of Alternaria tenuissima from India. *Indian Journal of Mycology and Plant Pathology* 13 (1): 94.

Natarajan, M.R. and Lalithakumari, D. 1987. Antifungal activity of the leaf extract of Lawsonia inermis on Drechslera oryzae. *Indian Phytopathology* 40 (3): 390-395

Quiniones, S.S. and Dayan, M.P. 1981. Notes on the diseases of forest species in the Philippines. *Sylvatrop* 6 (2): 61-67.

Pandey, M.K.; Singh, A.K. and Singh, R.B. 2002. Mycotoxic potential of some higher plants. *Plant Disease Research* 17(1): 51-56.

Rafiq, M.; Jabri, A; Khan, T.A. and Husain, S.I. 1991. Effect of bark extracts of some angiosperms on the larval hatching of Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949. *Current Nematology* 2 (2): 175-176.

Rai, M.K. 1996. In vitro evaluation of medicinal plant extracts against Pestalotiopsis mangiferae. *Hindustan Antibiotics Bulletin* 38 (1-4): 53-56.

Ravi, S; Valluvaparidasan, V.; Doraiswamy, S. and Jayalakshmi, C. 2000. Production of Colletotrichum lindemuthianum free French bean seeds. *Legume Research* 23 (3): 170-173.

Satish, S.; Raveesha, K.A. and Janardhana, G.R. 1999. Antibacterial activity of plant extracts on phytopathogenic Xanthomonas campestris pathovars. *Letters in Applied Microbiology* 28 (2): 145-147.

Sharma, N.D. and Singh, S.R. 1992. Some records of fungi from central India. *JNKVV Research Journal* 26 (2): 47-48.

Shenoi, M.M.; Murthy, K.K.; Sreenivas, S.S. and Wajid, S.M.A. 1999. In vitro evaluation of botanicals for mycotoxic properties against Alternaria alternata causing brown spot disease of tobacco. *Tobacco Research* 24 (2): 77-81.

Singh, A. and Singh, D.K. 2001. Molluscicidal activity of Lawsonia inermis and its binary and tertiary combinations with other plant derived molluscicides. *Indian Journal of Experimental Biology* 39 (3): 263-268.

Singh, J. and Tripathi, N.N. 1995. Fungitoxicity of some green plants against Fusarium oxysporum causing wilt disease in lentil. *Journal of Living World* 2 (1): 7-9.

Singh, M.P. 1982. Studies on the damage of castor semilooper, Achaea janata Linn to some fruit plants and its chemical control. *Indian Journal of Plant Protection.* 10 (1&2): 37-39.

Singh, S. and Sharma, G. 2003. Efficacy of different oils as grain protectant against Callosobruchus chinensis in green gram and their effect on seed germination. *Indian Journal of Entomology* 65 (4): 500-505.

Singh, V. and Yadav, D.S. 2003. Efficacy of different oils against pulse beetle, Callosobruchus chinensis in greengram Vigna radiata and their effect on germination. *Indian Journal of Entomology* 65 (2): 281-286.

Song, Bin and Li, Tai Hui. 2002. New species of the genus Asterina from China. *Mycotaxon* 84: 407-412.

Stephan,Z.A. 1988. Newly reported hosts of root-knot nematodes in Iraq. *International Nematology Network Newsletter* 5 (3): 36-43.

Tantaoui, A. 1993. Bayoud disease of date palms: density and distribution of Fusarium oxysporum f.sp. albedinis among Fusarium spp. populations in soil and prospects for direct control. *Al Awamia* 82: 3-24.

Teotia, R.S. 1995. New host records of fungi. *Indian Phytopathology* 48 (4): 492.

Verma, S.K. 2003. New Insect Problems in Arid Ecosystem. *Annals of Arid Zone* 42 (2): 165-177.

Zareie, R.; Shayesteh, N. and Pourmirza, A.A. 2003. Starch encapsulating of Bacillus thuringiensis Berliner containing different additives and evaluation of their efficiency. *Iranian Journal of Agricultural Sciences* 34 (4): 855-862.

Composition of Henna Powder, Quality Parameters and Changing Trends in its Usage

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Henna is used for dyeing and staining hair or skin primarily in the form of wet pack of its dried leaf powder. This form of usage is advantageous because the natural dyes are not very stable in solution and are prone to oxidation, browning, discoloration, pH colour shift, fading and attack by UV light. However, these adverse effects are less applicable to the dry powdered natural dye stuff either dry or as wet packs.

Thus, considering the common use of henna leaf powder in the formulation of dyeing products it is necessary to understand the nature of henna powder and its various quality parameters.

Physical Constituents

Being pulverised leaves the henna powder consists of the physical remnants of the diverse histological features of whole henna leaf. These include broken pieces of cuticle and epidermis of leaf lamina, monoclinal crystals of calcium oxalate (about 15 to 40 microns in diameter), rosettes of leaf parenchyma tissue or druses, sections of vascular bundle fibres and vessels with annular thickenings. Further, the air-dried leaf powder contains about 3 to 10 per cent moisture and minor volatile substances.

During processing of the leaves care is required to remove all type of foreign matter including branches and berries of henna. Many a times farmers also remove berries from the standing crop in the field (Fig. 1) as it adds to the value of the produce and may also lead to increase in the leaf growth.

Chemical Constituents

Henna powder is rich in colouring pigments amounting to about 12 to 15 per cent by weight (Paranjpe, 2001). Among them lawsone or 2-hydroxy-1,4-naphthoquinone is the main dye compound for which henna is famous as a natural dyestuff (Lal and Dutt, 1933). It occurs at varying concentration from less than 1.0 to about 3.0 per cent or even more in rare occasions.

Besides the photosynthetic and non-photosynthetic pigments, the powder contains gallic acid, glucose, mannitol, fats, resins (about 2 per cent) and mucilage (CSIR, 1962). Other organic compounds found are luteolin and its glucosides; lacoumarin (Bharadwaj *et al.*, 1976); laxanthones I, II and III (Bharadwaj *et al.*, 1977, 1978); fraxetin, scopoletin and esculetin (Chemical Abstr. 1982, 97: 107-108); and the phenolic glucosides lawsoniaside and lalinoside (J. Nat. Prod. 1988, 51:725).

Quality Parameters

Henna powder quality is determined by its colour, purity, its dyeing property and fineness (BIS, 1985). The colour of powder is based on the colour of the dried leaves and varies from olive green to brown. It seems to be influenced by the original harvest and subsequent drying (curing) conditions. In a study conducted at Pali it was found that leaf harvesting/drying time affected the powder colour (Table 1). However, the colour appeared to be unrelated to its dye content.

Further, in case of leaves getting moist while drying the leaves turn on a dark rusty brown colour due to the leaching out of the dye and produce brown coloured powder. The processing conditions under which the powder is prepared may also affect powder colour. Higher processing temperature during grinding is known to increase browning of powder and loss of pigments presumably due to more of oxidation of pigments under such conditions. In general, the consumer acceptability is higher for green colour, perhaps because this colour is sensed as proof of the herbal origin, freshness and purity of the powder.

Table 1. Henna powder colour and dye content as affected by time of harvest

Month of harvest and curing*	Powder colour	Lawsone content (%)
June	Rusty brown	2.38
July	Greenish brown	2.68
August	Brown	2.75
September	Yellowish brown	2.60
October	Green	2.82

* Leafy branches were cut and air dried in the open under shade away from direct sunlight at room temperature and the dried leaves obtained were ground to fine powder using laboratory grinding mill.

Pure henna powder has considerable amount of water-soluble constituents. Cold water extraction of dry powder yields about 25 to 32 per cent of water-soluble matter. The range of other constituents of pure henna powder as specified under the Indian standards is: crude fibre 10 to 15 per cent, mineral matter 8 to 12 per cent, acid insoluble ash 3 to 6 per cent and lawsone pigment at least 1.0 per cent by mass (BIS, 1985). Table 2 presents the comparative values of these quality parameters obtained in a sample of henna powder from Sojat (Pali) in Rajasthan. The sample broadly conforms to the requirements. Lawsone content is highly satisfactory. It also meets the minimum requirement of fineness of the powder (indicated by the material passing through 250 micron sieve) that should be at least 95 per cent whereas in the sample tested it is around 96 per cent. Extraneous sand is slightly more and it may not be desirable to have more than 5 per cent of such matter.

Table 2. Quality of henna powder from an Industrial unit at Sojat (Pali) in Rajasthan (Test method IS 7159:1984)

Characteristic	Estimated value (% mass)
pH (1% solution)	5.7
Moisture and volatile matter	3.4
Cold water extract	26.0
Crude fibre	9.3
Mineral matter	12.3
Acid insoluble ash	5.4
Extraneous sand	6.3
Lawsone content	2.4
Presence of extraneous dyes	Not detected
Fineness of powder (i.e material passing through 250 micron sieve)	95.9

Lawsone dye present in henna powder is an acid mordant dye and stains well in acid bath. It naturally imparts a reddish orange stain on binding to the keratin of hair and skin surface. Areas with more layers of dead skin stain deeper to produce brown or dark brown colour. The henna powder having this dyeing quality is generally categorised as 'red henna'. However, some henna powder produces black or very deep brown shades. These are acknowledged as 'black henna'. There is mention in literature that mixing of henna and indigo in different proportions can give shades of brown on hair, but not on the skin. A mixture of one part of henna and two parts of indigo, Henna-Rang as is called, imparts a brown tint, while henna-rang containing one part henna and three parts of indigo gives a dark brown colour (Hill, 1955)

As most of the henna powder is consumed in preparing hair dye and black is the natural hair colour of choice, sometimes the henna powder may be charged with extraneous dyes in order to change the colouring potential to black. Use of synthetic black dyes like PPD i.e. para-phenylenediamine in the henna powder in the past proved unhealthy and detrimental to the safety of henna powder. HPLC methods are now available to identify and quantify para-phenylenediamine in black henna samples (Brancaccio *et al.*, 2002).

Number of other salts and dyes are combined with henna to produce various shades. The original colour of henna is only one orange red. Its intensity can vary due to variation in lawsone content and frequency of use. To get different shades of colour there are number of folk tips like addition of allspice, cinnamon or nutmeg, apple cider vinegar or lemon juice; egg yolk or whole egg; cloves or clove oil; cognac, tea, coffee, etc. It is possible that many of the formulations in market are combination of various plant products, but no quality standards could be traced for such products in the country.

Fig. 1. Ladies removing berries before harvest of the crop

Changing Trends in Usage of Henna

Henna is possibly the worlds oldest cosmetic and is still used widely all over the world. According to Catherine Cartwright (2001) there is very persuasive evidence that henna was used as early as 7000 BC by the Neolithic people. The early centre of the use of henna as a woman's adornment seems to have been the eastern Mediterranean, where it grows wild. It is mentioned in the Bible as "Camphire" in the Song of Solomon, and was used by the Canaanite women in pre-biblical times. Henna was used in Palestine from the earliest historical period, and there are Roman records of henna being used by Jewish people living in Jerusalem during the historical period of the birth of Christ. When Islam began in the 6-7th centuries AD, henna was incorporated into the customs of Muslims. As Islam expanded quickly into other countries, the use of henna went with it. Henna was grown and used in Spain, by Christians and Moors from the 9th century AD to 1567 when the Spanish Inquisition outlawed it.

In India, henna is seen frequently on women in miniature paintings after 1500 AD, though patterning is very rare until after 1700 AD. In Hindu India during this period, henna certainly is part of the cosmetic routine used by wives and concubines to look their best. Henna is also depicted on Kali and other Hindu deities during this period, and up to the present day. By 1700, the bridal celebration of the Night of the Henna was a well-established part of Muslim India's traditions. A portrait of Mumtaz Mahal has one of the earliest patterned hennas on her hands. Dip henna and simple patterns adorn most women portrayed in Indian art since 1800. Henna patterning in India has become very complex and beautiful in the 20th century, and is used as part of the celebration.

Mehndi is an art using henna as an expression of cultural or spiritual meaning. The art varies from country to country, spanning different cultures and religious traditions, and making it possible to recognize distinctions in cultural style. There are three main traditions that can be recognized, aside from the modern use of henna as a trendy temporary tattoo. Generally, Arabic (Middle-eastern) mehndi features large, floral patterns on hands and feet, while Indian (Asian) mehndi uses fine line, lacy, floral and paisley patterns covering entire hands, forearms, feet and shins; and African mehndi art is large, and bold with geometrically patterned angles. African mehndi patterns usually use black henna while Asian and Middle Eastern mehndi is often reddish brown (Anon. 2004).

Many countries like USA and Germany recommend henna usage only as a hair dye. Even though Ame's Test shows that henna is not mutagenic, but para-phenylene diamine/ 1,4-phenylenediamine (PPD), a common adulterant, has mutagenic activity. Black henna generally contains high amounts of PPD. PPD itself is not black nor has any smell. Many products on sale in the local market may be adulterated with PPD. PPD has many names like PARA, p-aminoaniline, C.I 78080, P-diaminobenzene, Zoba black D and many others. Thus henna should not be used by pregnant women (in Africa henna has been used to induce abortions), both men and women actively dealing with fertility problems or undergoing treatment for such, people with a G6PD-deficiency and people with skin sensitivities, allergies to para-phenylenediamine (PPD) etc.

References

Anonymous 2004. Beautiful art of mehndi-history. www.*Beautiful art of mehndi-history*.com

Bhardwaj D.K., Jain R.K., Jain S.C., Mehta C.K. 1978. 1-Hydroxy-3,7-dimehtoxy-6-acetoxyxanthone, a new xanthone from *Lawsonia inermis*. *Phytochemistry* 77: 1440-1441.

Bhardwaj D.K., Murari R., Seshadri T.R., Singh R. 1976. Lacoumarin from *Lawsonia inermis*. *Phytochemistry* 75: 1789.

Bhardwaj D.K., Seshadri T.R., Singh R. 1977. Xanthones from *Lawsonia inermis*. *Phytochemistry* 76: 1616-1617.

BIS. 1985. Indian Standard Specification for henna powder (IS: 111421984), First reprint 1997, *Bureau of Indian Standards*, New Delhi, pp 8.

Brancacco RR, Brown LH, Chang YT, Fogelman JP, Mafong EA and Cohen DE. 2002. Identification and quantification of para-pheneylenediamine in a temporary black henna tattoo. *Am.J. Contact Dermat.* 13(1):15-18.

Cartwright Catherin and C. Jones. 2001. Abrief history of henna. www.The henna page-The history of henna.com

CSIR. 1962. The Wealth of India Vol VI: L-M, *Council of Scientific and Industrial Research*, New Delhi, pp 47-50.

Hill 1955. Brochure marketing Henna 1955, 7-8: 129 (as mentioned in wealth of India, CSIR publication).

Lal, J.B. and Dutt, S. 1933. Constitution of the colouring matter of *Lawsonia alba* Lam., or Indian mehndi. *J. Indian Chem. Soc.* 10: 577-582.

Paranjpe, P. 2001. Indian Medicinal plants - Forgotten healers. Chowkhamba Sanskrit Pratisthan, Delhi, pp 316.

Lawsone : Biosynthesis, Estimation, Extraction and its Derivatives

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Lawsone, a secondary plant metabolite, is used as natural colorant. The compound belongs to quinone group and has been identified as 2-hydroxy-1,4-naphthoquinone. It is the major constituent of henna powder that is made by powdering dried leaves of *Lawsonia inermis*. Tribal women (Bhils) in Udaipur (Rajasthan) use *Impatiens balsamina* flowers as a substitute of henna dye (Sharma, 1999). Lawsone and related naphthoquinones have also been isolated from *Impatiens balsamina*, *I. capensis*, *I. pallida*, and other *Impatiens* species (Thompson, 1971). Lawsone and its derivatives have various uses in agriculture and medicines besides the cosmetics industry.

Lawsone in crystalline form appears as yellow needles with m.p. 190°C and shows UV absorption at λ_{max} (C_2H_5OH) 245.5, 248, 274, 334 nm (logε 4.17, 4.21, 4.14, 3.40). Its absorption in IR region occurs at wave number ν_{max} (KBr) 3150, 1674, 1640 cm^{-1}.

Biosynthesis

In the plant lawsone is synthesised through the succinyl benzoate pathway. In this pathway chorismic acid (chorismate), an intermediate of the shikimic acid pathway, reacts with α-ketoglutaric acid from the Tricarboxylic acid cycle to form succinyl benzoate (succinyl benzoic acid). The later, in turn, is converted to lawsone as in henna or some other quinones in plants, e.g., juglone (5-hydroxy-1,4-naphthoquinone) in *Juglans* species of Juglandaceae family, and alizarin (an anthraquinone) in plants of the Rubiaceae family(Strack, 1997).

The succinyl benzoate pathway initially involves the conversion of chorismate (chorismic acid) to its isomer isochorismate by the enzyme isochorismate hydroxymustase. Isochorismate in turn is converted to 2-succinyl benzoic acid in the presence of 2-oxoglutarate and thiamine pyrophosphate. This reaction constitutes a new aromatisation process. Subsequently the succinyl benzoate is activated at the succinyl residue to give a mono-CoA ester, requiring ATP in the process. The metabolic steps beyond the CoA-ester leading to the synthesis of quinones including lawsone are unknown. However, the formation of 1,4-naphthoquinone, the intermediate product leading to juglone (an isomer of lawsone) synthesis was reported by Strack (1997). Lately, De-Eknamkul (1999) generated information on the biosynthesis of lawsone in *Impatiens balsamina*, the other known source of lawsone besides henna.

In vitro root culture studies of *Impatiens balsamina* by De-Eknamkul (1999) confirmed the biosynthesis of lawsone from succinyl benzoic acid (Fig 1). It was found that the feeding of radiolabelled α-ketoglutaric acid precursor to the cultured roots effectively led to the labelling of both lawsone and its methylated form (Me-lawsone) produced in the roots. This clearly demonstrated the role of α-ketoglutaric acid as precursor in lawsone biosynthesis. However, during this process no labelled intermediates could be detected and led De-Eknamkul (1999) to suggest that the conversion of succinyl benzoic acid to lawsone was rapid and regulated by multiple enzymes organised tightly as high molecular weight enzyme complex. The enzyme o-methyltransferase involved in the methylation of lawsone in *I. balsamina*, however, appeared to be loosely bound to this enzyme complex as addition of non-labelled lawsone interfered with the concentration of labelled Me-lawsone produced in the root. CoASH, ATP and Mg^{2+} were important cofactors in the conversion of succinyl benzoic acid to lawsone.

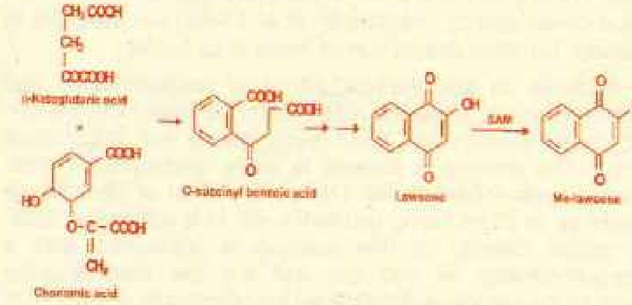

Fig. 1. Biosynthetic pathway of lawsone proposed by De-Eknamkul (1999)

Degradation : Lawsone gets degraded in humus. Wessendorf *et al.* (1995) isolated a bacteria, *Pseudomonas putida* strain L2 that is capable of using lawsone as sole source of carbon and energy. Salicylic acid and catechol were isolated as intermediates during degradation. Salicylic acid is converted to catechol by salicylate 1-monooxygenase. Catechol 1,2-dioxygenase catalyses ortho-fission of catechol, which is then metabolized via the β-ketoadipate pathway.

Extraction and Chemical Synthesis

Lawsone can either be extracted from henna leaves or can be synthesised from 1,4-napthoquinone. For its extraction, crushed henna leaves are treated with aqueous sodium carbonate. The solution is acidified and extracted with chloroform. Upon removing the solvent crude lawsone is obtained. Lawsone of high purity can be produced either by column chromatography or thin layer chromatography. Lawsone can also be prepared in the laboratory through Thiele-Winter acetoxylation. 1,4-Napthoquinone is treated with acetic anhydride in the presence of an acidic catalyst. The derivative so obtained is hydrolysed to hydroxyhydroquinone derivatives which on oxidation yields desired hydroxyquinone compounds. Lawsone can also be prepared from 1,3-dehydronaphthalene as shown below.

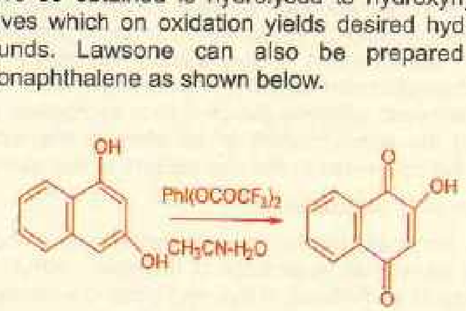

Fig. 2. Synthesis of lawsone from 1,3-dehydronaphthalene

Catalytic conversion of 2-naphthol to 2-hydroxy-1,4-naphthoquinone has been achieved by Yan *et al.* (2004) under mild conditions. It involves catalytic oxidation of 2-napthol by molecular oxygen over tetra(4-methoxyl-phenyl)porphyrinate iron(III) chloride catalyst in an alkali methanol solution at 50°C.

Estimation of Lawsone Content

Price of henna leaves or powder in the market is dependent on its lawsone content and purity. It is therefore useful to quantify lawsone content in henna leaf material. It can be estimated by spectrophotometric or chromatographic methods as described in the following paragraphs.

Spectrophotometric methods

Two water extraction spectrophotometric methods, the one advocated by BIS i.e. Bureau of Indian Standards (ISI) (IS:7159-1984; reaffirmed 1995; Amendment No I & 2 April 1990 & July 2004) and another one developed by Pratibha and Korwar (1999), and one solvent extraction spectrophotometric method developed by Vardanyan *et al.* (1986) are available in literature. The brief description of these is as below :

BIS method: In this method 2.0 g of prepared (dry leaf powder) sample is soaked in 100 ml of 5 per cent (w/v) sodium bicarbonate solution for about eight hours with intermittent shaking. The mixture is allowed to settle overnight and then filtered through a filter paper. Thereafter, 10 ml of clear filtrate is made up to 25 ml using distilled water in a volumetric flask. The optical density of this solution is measured with a spectrophotometer at 490 nm and the per cent lawsone content in the sample is determined by referring to a calibration curve prepared at this wavelength using 0 to 50 ppm concentration of lawsone.

Method by Pratibha and Korwar (1999): It is a relatively simple method and requires less time. The procedure of this colorimetric method involves the soaking of 100 mg finely ground leaf material of henna in 20 ml water for two hour period. Thereafter the mixture is centrifuged for 20 min at 5000 rpm and the clear supernatant is separated out in a test tube. The absorbance of the supernatant is measured at 452 nm wavelength. Further, a calibration curve is prepared by plotting the concentration versus the absorbance at this wavelength in the concentration range 0 to 70 ppm of the pure dye. The lawsone content in the sample is then calculated as: Lawsone in sample (mg/g) = PPM in test solution x dilution factor.

The method is useful for comparative studies. Our studies suggest that the estimates of lawsone get affected by pH and best results are obtained near neutral pH.

Solvent extraction method of Vardanyan *et al.* (1986): Under this method 150-200 mg powdered leaves of henna is digested in 80 ml alkaline distilled water (pH 9-9.5) at 80°C for half an hour and thereafter the digested mixture is filtered. On reaching the room temperature the extract is made up to 100 ml volume with distilled water and acidified to pH 4.5 5.0 using HCl. Lawsone in the aqueous solution is then extracted with chloroform at 1:1 ratio. The separated organic layer is dried using sodium sulphate and its absorbance recorded in an UV-visible spectrophotometer at 338 nm wavelength. Based on the relationship between lawsone concentration and optical density (absorbance) the concentration of lawsone in the extract is worked out and converted to the dye content of leaf sample.

Chromatographic methods

Thin layer chromatography is commonly used both for identification as well as estimation of lawsone. HPLC is also useful in analysis of mixtures of dye and other chemicals.

TLC Identification : To identify the presence of lawsone, extract 20 g of powder with 150 ml n-hexane using Soxhlet apparatus so as to remove fats and then extract the dye with methanol for 8-10 hours, and concentrate the solution under low pressure before using it for TLC. One mg of lawsone in one ml of methanol may be taken as reference. Apply about 20μl of the sample as well as standard on TLC plate made using silica gel (thickness = 0.2 mm) and run the plate using solvent system of TEA that is Toluene: Ethyl acetate : Acetic acid (5 : 4 : 1). For visualising the spots, spray the plate with ten per cent ethanolic potassium hydroxide and observe in normal light. The lawsone appears as blood red spot with Rf value of around 0.6.

High Performance TLC method : For chromatographic estimation of lawsone, the TLC plates are prepared by using silica gel 60 and are of 0.2 mm thickness as in the identity test. The gels loaded with known quantity of the sample and standard solution are run using TEA and developed by spraying 10% ethonolic KOH (followed by heating at 110° C for 30 min). These are scanned at 560 nm for estimation of lawsone in the sample. The peak area of the sample compared with the calibration curve provides an estimate of the dye content. This method is commonly used for estimation of lawsone in the drugs (Quality Standards of Indian Medicinal Plants, Vol.1).

HPLC method : Various methods of lawsone estimation using HPLC are available in literature and the latest one reported by Yan *et al.* (2004) involves the following conditions: Hypersit ODS, 10 ; Pressure, 7.9 Mpa; Mobile phase, H_2O_2/MeOH/MeCN (2v/1v/1v); flow rate, 1ml/min. Lobstein *et al.* (2001) developed and validated a convenient and reliable reversed phase HPLC method for quantitative determination of naphthoquinones present in the aerial parts of *Impatiens glandulifera*. Many a times para-phenylenediamine is added to henna powder and is labelled as black henna. This chemical is known to have adverse reactions on skin. Brancaccio *et al.* (2002) used HPLC to identify and quantify lawsone and para-phenylenediamine in temporary black henna tattoo.

Lawsone Derivatives

Naphthoquinones having hydroxy groups directly attached to the quinone ring constitute a very interesting class of compounds, and the majority of the compounds from this group exhibit unique biological activity. The most representative natural naphthoquinone with bioactivities is vitamin K known as antihemorrhage vitamin. Naturally occurring hydroxyquinones are attractive synthetic targets due to their biological activity and their participation in biochemical processes (Spyroudis, 2000). The chemical and biological activity of quinone is largely dependent on the substituents present either on the quinonic or on an adjacent rings. Substituents can be introduced into the molecule by several ways like substitution, cyclisation, addition reactions, etc. Lawsone is one of the simplest hydroxyquinone. Preparation of some of the lawsone derivatives is discussed here.

Alkyl substitution

There are relatively few reports on the alkylation of hydroxyquinones. One of the first methods was the reaction of diacyl peroxides with lawsone to produce a great variety of naphthoquinones possessing antimalarial activity (Fieser *et al.*, 1948). Better results are obtained from the reaction of acylated lawsone with a carboxylic acid in the presence of peroxysulfate-mediated radical decarboxylation reaction (Khambay *et al.*, 1997). Nanomycin is the antibiotic having the 5-hydroxy-1,4-naphthoquinone structure. In the field of animal drugs, 2-methyl-1,4-naphthoquinone is used as a hemostatic, a feed additive. Many of the naphthoquinone derivatives can be also utilized for the infection drugs as anti-fungal agents, anti-virus medicines and antibacterial agents.

Many of naphthoquinone derivatives have potential pesticidal activities. Lapachol a potential pesticide can be synthesized on preparative scale from lawsone (Sun *et al.*, 1998). In the first step, lithium salt of lawsone is prepared by addition of lithium hydride to a frozen solution of the lawsone in dimethyl sulfoxide. The lithium salt so formed is alkylated with 3,3-dimethylallyl bromide to produce lapachol. Lapachol is also known as anti-microbe and anti-protozoal for a long time, and a lot of its derivatives have also been developed.

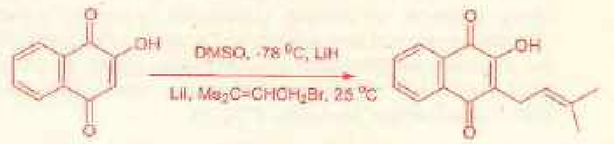

Fig. 3. Conversion of lawsone into lapachol

Alkyl group can directly be introduced at position C-3 by the reaction of lawsone with alkylborane (Bieber *et al.*, 1999). The product thus obtained is oxidatively hydrolysed to produce alkyl lawsone. Aryl group can also be introduced at position C-3 of lawsone by its reaction with diazonium salts under alkaline conditions (Brassard and L'Ecuyer, 1958).

Different 2-hydroxy-3-alkyl-1,4-napthoquinones have been shown to have herbicidal activity (maximum *in* vitro activity by nonyl to dodecyl homologues) and the mode of their activity is through inhibition of photosystem II (Philip *et al.*, 2002). 2-Amino-3-chloro-1,4-naphthoquinone is also a herbicide and it is reported that the herbicidal activity rises when substituents such as amino group, chloro group or thioalkyl group are introduced at the 2 or 3 position of the naphthoquinone. 2,3-Dicyano-1,4-dithia-9,10-anthraquinone is a fungicide developed by Merck & Co., Inc. in Germany. Derivative 2-acetoxy-3-dodecyl-1,4-naphthoquinone is a miticide that has been reported to be synthesized from lawsone.

Furan derivatives

Napthofuranodiones are natural products exhibiting a broad spectrum of biological activity. These can be prepared by reaction of lawsone with 2-bromopropanal through initial alkylation of C-2 (Huot and Brassard, 1974). When lawsone is treated with 3,4-dibromo-2-butanone, a mixture of furan and dehydrofuran derivatives is obtained. Dehydrofuran and furan derivatives/analogues can also be prepared by the regioselective (3+2) photo addition of lawsone with alkenes and alkynes, respectively (Kobayashi *et al.*, 1991, 1993).

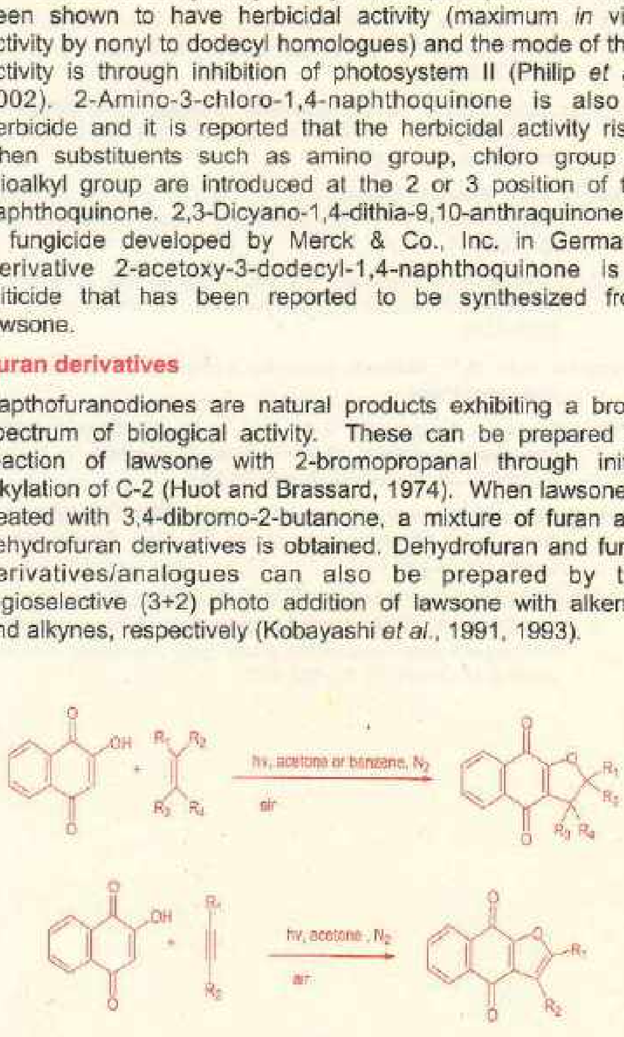

Fig. 4. Regioselective photoaddition of lawsone with alkenes and alkynes

Some of the other cyclisation reactions include formation of 2,2-dichloroindane-1,3-dione through analogous oxidative transformation of lawsone in presence of $FeCl_3$, $HClO_4$ and AcOH (Singh and Khanna, 1994).

Lawsone also undergoes various reactions within the plant system of henna as many naturally occurring derivatives of lawsone have been reported from henna. For example, 2-methyl-8-hydroxy-1,4-naphthoquinone (isoplumbagin) was isolated from stems of henna (Sarita-Gupta *et al.*, 1993). This compound has been shown to cause 100 per cent mortality *in-vitro* of root knot nematode as compared to 58 per cent of lawsone at concentrations of 200 μg/10 ml in water (Dama, 2002).

Henna, in which lawsone is the active ingredient, has been widely used for colouring hair and skin since early time. It is also used for various purposes in tradition medicine and modern research has validated many of these usages. It acts as immunoinhibitory, immunostimulatory (Ali, 1996); as an astringent and prophylactic agent against skin-diseases (Anand *et al.*, 1992). It is also effective in treating ringworms in calves (Bosoglu *et al.*, 1998). *L. inermis* has also been shown to have broad-spectrum antimicrobial activity (Ahmad and Beg 2001) against bacteria such as *Staphylococcus aureus*, and other bacteria. It is also reported to have antiviral properties. Bark extract of *L. inermis* is of therapeutic value in treatment of jaundice, and enlargement of spleen (Anand *et al.*, 1992). Lawsone has been shown to inhibit HIV virus from copying and propagating as it prevents the formation of protein coenzyme of HIV-I. Lawsone derivatives and dichloroallyl lawsone are also the inhibitor of RNA synthesis in cancer tissue.

Similarly there are numerous reports of use of lawsone in agriculture for control of plant diseases caused by fungi, bacteria or nematodes. There have been innovative uses of lawsone and it has been used for staining of intestinal protozoa (Nor-Afandy *et al.*, 2002), staining agent for proteins in polyacrylamide gel electrophoresis (Ali and Sayed, 1997), for differentiation between inactive living and dead nematodes (Gaur and Chandel, 1998). Henna is harmless to the skin. Allergic reaction is rare. No mutagenic activity has been observed in Ames' test. Thus, there is great scope of using lawsone, and its derivatives for use in medicine, agriculture and cosmetics.

References

Ahmad I and Beg AZ. 2001. Antimicrobial and phytochemical studies on 45 Indian medicinal plants against multi-drug resistant human pathogens. *Journal of Ethnopharmacology.* 74: 113-123.

Ali M 1996. Chemical and medicinal evaluation of Lawsonia inermis (henna). *Hamdard Medicus* 39(4): 43-48.

Ali R. and Sayeed SA. 1997. Lawsone: phenolics of henna and its potential use in protei-rich foods and staining. *Antinutrients and phytochemicals in food*, Washington, DC (USA) p 223-244.

Anand KK, Singh B, Chand D and Chandan BK 1992. An evaluation of Lawsonia alba extract as hepatoprotective agent. *Planta Medica* 58: 22-25.

Bieber, L.W., Neto, P.J.R., Generino, R.M. 1999. Regioselective alkylation of substituted quinones by trialkylboranes. *Tetrahedron Lett.* 40: 4473-4476.

Bosoglu A, Birdane F and Solmerz H 1998. The effect of henna (Folium lawsonia) paste in ringworm in calves. *Indian Veterinary Journal* 75: 71-72.

Brancaccio RR, Brown LH, Chang YT, Fogelman JP, Mafong EA and Cohen DE. 2002. Identification and quantification of para-pheneylenediamine in a temporary black henna tattoo. *Am.J. Contact Dermat.* 13(1):15-18.

Brassard, P. and L'Ecuyer, P. 1958. Arylation of quinones by diazonium salts. IV. Reaction of these salts with 2,5-dihydroxy-p-benzoquinone and the synthesis of 3-hydroxy-2,5-diphenyl-p-benzoquinone. *Can. J. Chem.* 36: 1346.

De-Eknamkul Wanchai. 1999. Chasing the key enzymes of secondry metabolits biosynthesis from Thai medicinal plants. *Pure Appl. Chem.*, 70:1998 URL:http://www.iupac.org/symposia/proceedings/phuket97/de-eknamkul Copyright 1999 IUPAC

Dama, L.B. 2002. Effect of naturally occurring napthoquinones on root-knot nematode *Meloidogyne javanica*. *Indian Phytopathology* 55: 67-69.

Fieser, L.F., Berliner, E., Bondhus, F.J., Chang, F.C., Dauben, W.G., Ettinger, M.G., Fawaz, G., Fields, M., Heidelberger, C., Heymann, H., Vaughan,W.R., Wilson, E., Moore, E.E., Moore, M.B., Zaugg, H.E. 1948. Naphthoquinone antimalarials. IV-XI. Synthesis. *J. Am. Chem. Soc.*, 70: 3174.

Gaur Hsand Chandel ST 1998. Indigenous non-toxic herbal stains for differentiation of live and dead nematodes. *Annals of Plant Protection Sciences.* 6: 216-219.

Huot, R. and Brassard, P. 1974. Synthese de methyl-3 furoquinones. *Can.J. Chem.* 52: 88-94.

ISI. 1985. Indian Standard Methods of Test for Henna Powder (first revision), IS:7159-1984, Indian Standards Institution (Bureau of Indian Standards), New Delhi, pp. 9 + Amendment No.1 & 2 of April 1990 and July 2004.

Khambay, B.P.S., Batty, D. Beddie, D.G., Denholm, I., Cahill, M.R. 1997. A new group of plant-derived naphthoquinone pesticides. *Pestic. Sci.* 50: 291-296.

Kobayashi, K., Kanno, Y., Suginome, H. Photoinduced molecular transformations. Part 141. 1993. New one-step general synthesis of benzofuran-4,7-diones by the regioselective (3+2) photo-addition of 2-hydroxy-1,4-benzoquinones with various alkenes. *J. Chem. Soc. Perkin Trans.* 1: 1449-1452.

Kobayashi, K., Shimizu, H., Sasaki, A., Suginone, H. 1991. New one-step synthesis of 2,3-dihydronaphtho[2,3-b]furan-4,9-diones by regioselective [3+2] photoaddition of 2-hydroxy-1,4-naphthoquinones with various alkenes and its application to a two-step synthesis of maturinone. *J. Org. Chem.* 56: 3204-3206.

Lobstein, A., Brenne, X., Feist, E., Metz, N., Weniger, B. and Anton, A. 2001. Quantitative determination of naphthoquinones of *Impatiens* species. *Phytochemical Analysis* 12: 202-205.

Nor-Afandy H, Noor-Hayati MT, Chan BTE, Ismail MG, Chag Y (ed.) 2002. Staining of intestinal protozoa (*Entoamoeba* spp.) using extracts of henna (*Lawsonia inermis*), pandan (*Pandanus odorus*) and a commercial dye. In *Proceedings of the seminar on Medicinal and aromatic plants* 24-25 July 2001, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abd. Kuala Lumpur, Malaysia. P 69-71.

Philip JJ, James H, Kate JB, Stephen RM, Adrian BB and Bhupinder PSK. 2002. Herbicidal action of 2-hydroxy-3-alkyl-1,4-napthoquinones. *Pest Management Science* 58: 234-242.

Pratibha, G. and G.R. Korwar 1999. Estimation of lawsone in henna (*Lawsonia inermis*). *Journal of Medicinal and Aromatic Plant Sciences* 21: 658-660.

Sarita-Gupta, Mohd-Ali, Alam, M.S., Gupta, S. and Ali, M.1993. A naphthoquinone from *Lawsonia inermis* stem bark. *Phytochemistry* 33: 723-724.

Sharma, S.K. 1999. Plants used as henna dye by Bhils of southern Rajasthan. *Journal of Economic and Taxonomic Botany*, 23: 257.

Singh, P. and Khanna, R. 1994. Synthesis of 2,2-dichloroindane-1,3-diones from 1,4-naphtho-quinones. *Tetrahedron Lett.* 35: 3753-3754.

Spyroudis Spyros 2000. Hydroxyquinones: Synthesis and Reactivity. Molecules, 5: 1291-1330 (ISSSN 1420-3049, http://www.mdpi.org).

Strack, D. 1997. Phenolic metabolism. In: *P.M. Dey and J.B. Harborne (eds.) Plant Biochemistry.* Academic Press, California, USA, pp. 387-416.

Sun, J.S., Geiser, A.H., Frydman, B. 1998. A preparative synthesis of lapachol and related naphthoquinones. *Tetrahedron Lett.* 39: 8221-8224.

Thompson, R.H. 1971. Naturally occurring quinones. 2nd edn. London, Academic Press.

Vardanyan, M.K., Nersisyan, S.A. and N.S. Mashanova 1986. Spectrophotometrical determination of lawsone in henna. *Biological Journal of Armenia* 6: 55-57.

Wessendorf, J., Rettenmaier, H. and Lingens, F. 1995. Degradation of lawsone by *Pseudomonas putida* L2. *Biol. Chem. Hoppe Seyler* 10: 945-951.

Yan Y, Guo HW, Jian W-P, Yang Ke-Er, tong Shan-Ling, Fang C-G, Li Q and Chang X. 2004. Catalytic conversion of 2-naphthol to 2-hydroxy-1,4-naphthoquinone under mild conditions. *Chinese Journal of Chemistry* 22: 487-491.

Micropropagation of Mehndi (*Lawsonia inermis* L.)

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Lawsonia inermis is normally propagated through seeds and cuttings. Conventional methods of propagation have many limitations. Propagation through seed means large variability. In western part of Rajasthan, it is commercially grown in Sojat and Pali districts. A large biodiversity is available in this region; need identification, selection and multiplication of selected desirable germplasm. Cosmetic and pharmaceutical companies largely need materials of high and uniform quality from naturally occurring stands. Since cell and tissue culture methods are rapid methods in multiplication, conservation and improvement of elite germplasm can be exploited for the enhancement of quality in henna plant (Bakkali *et al.*, 1997; Rout *et al.*, 2001). Lawsone accumulation in normal and transformed cultures has been reported in *L. inermis* (Bakkali *et al.*, 1997) therefore development of *in vitro* techniques for mass propagation of *L. inermis* is highly warranted. The present study describes a successful method for mass propagation of *L. inermis* through tissue culture.

Young nodal segments and seeds of *L. inermis* were collected from the selected farmer's fields in Sojat and Jodhpur areas of Rajasthan. Explants were washed with 2 per cent (v/v) detergent 'Teepol' (Qualigen, India) and rinsed several times with running tap water. The treated explants were further surface sterilized in 0.1 per cent (w/v) aqueous mercuric chloride solution for 15 min followed by four washings with sterile distilled water. The nodal segments having axillary buds and seeds were used for raising cultures.

The axillary buds were placed on semi-solid half strength basal MMS medium (Murashige and Skoog, 1962; Raj Bhansali, 1995) supplemented with different concentrations and combinations of 6-benzylaminopurine (BAP: 0-5 mg/l), kinetin (KN: 0-5 mg/l), naphthalene acetic acid (NAA) (0-2 mg/l) for shoot proliferation, multiplication and rooting. The pH of the media was adjusted to 5.8 using 0.1N NaOH or 0.1N HCl before autoclaving. 25 ml medium was dispensed into culture tubes (25 x 200 mm) or 100 ml Erlenmeyer flasks and sterilized at 121° C and 1.06 kg cm^{-2} pressures for 20 min. The cultures were maintained at 28±2° C either under 16h photoperiod or continuous light (65 mmol $m^{-2}s^{-1}$) from cool, white fluorescent lamps. The cultures were maintained by regular subcultures at 3-week intervals on fresh medium. For root induction, excised shoots were transferred to 1/2 MMS basal medium supplemented with different concentrations of NAA (0-2 mg/l) or without hormone. Rooted micro-propagules were planted in pots containing a sterile mixture of sand: soil. Twenty cultures were used per treatment and each experiment was repeated at least three times. Cultures showing response, number of shoots/culture and mean percentage of rooting were recorded regularly.

Axillary Bud Proliferation and Multiplication

Bud proliferation and their multiplication were initiated from apical and axillary explants of nodal buds and seed explant tissues of *L. inermis* within 8-10 days of inoculation onto MMS basal medium supplemented with BA, KN and NAA. Among the different cytokinins tested, BA + KN were the most effective for shoot proliferation and multiplication. The maximum shoot proliferation was observed both in apical and axillary meristems cultured on MMS medium supplemented with 1 mg/l BA, 0.5 mg/l KN and 0.1 mg/l NAA within 4 weeks of culture. The shoots proliferated in large number as miniature plants from dark callus tissues or nodal buds. There was no sign of shoot proliferation when explants were cultured in media devoid of cytokinin. At higher concentrations of BAP or KN, the rate of shoot proliferation declined. Inclusion of higher amount of NAA in the culture medium did not help in proliferation and multiplication of shoot. In most of the cases, the growth was inhibited and only 1-2 shoots elongated; some produced compact dark coloured callus at the base of the explants. Prolonged culture on the proliferation and multiplication media resulted in the blackening of callus and at the basal ends of the developing shoots. There were huge differences among the hormonal treatments for both the percentage of cultures with multiple shoots and the mean number of shoots/culture. The axillary meristems produced more number of shoots (6.6) than the apical meristems (3.6) (Fig. 1).

Fig. 1. Proliferation of shoots from callus of apical bud of *Lawsonia inermis* on MMS medium supplemented with 1 mg/l BAP, 0.5 mg/l KN, 0.1 mg/l NAA and 3% sucrose

The study also revealed that the continuous light (24h) was more conducive to higher rate of shoot multiplication than 16h photoperiod. The highest percentage of cultures with multiple shoots was observed on media containing 1 mg/l BAP, 0.5 mg/l KN and 0.1 mg/l NAA. The rate of multiplication was high and stable with regular subculture after every 25 days (Fig.2).

Induction of Rooting

Elongated shoots (5-7.5 cm long) were rooted on MMS basal medium supplemented with various concentrations of either NAA or without any hormone. The rooting in the *in vitro* developed shoots was enhanced on ½ strength medium devoid of growth regulator and vitamins. Root initiation took place within 15 days of transfer to MMS basal medium supplemented with NAA (Fig. 3). However, optimal rooting and growth of micro-shoots was observed on medium containing NAA with 2% (w/v) sucrose within 25 days (Fig. 4). The rooting ability was reduced with the increase in the concentration of auxins in the culture medium. The percentage of shoots forming roots and days to rooting significantly varied with different concentrations of NAA.

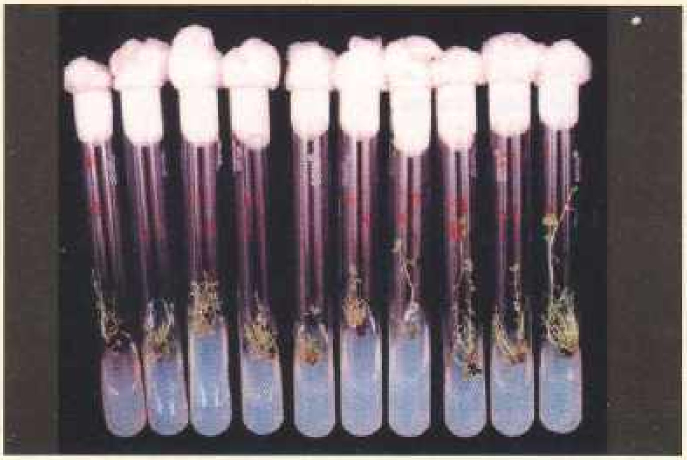

Fig. 2. Induction of multiple shoots of *Lawsonia inermis* on MMS medium supplemented with 0.5 mg/l BA, 0.25 mg/l Kinetin and 0.05 mg/l NAA after 25 days

Fig. 3. Elongation of separated shoots on ½ MMS medium without hormone and vitamins

Fig. 4. Rooting in the *in vitro* derived shoots on ½ MMS medium supplemented with 1 mg/l NAA and 2% (w/v) sucrose after 25 days

Acclimatization and Establishment

Rooted well developed plants grown *in vitro* were washed thoroughly to remove the agar and then transplanted to sterile pots containing garden soil, sand at the ratio of 2:1 (v/v). The plant grew well and attained 8-12 cm height within 4 weeks of transfer (Fig. 5). The acclimatized plants were established in the pot condition and grew normally without morphological variation.

The improvement of axillary shoot formation of *L. inermis* has been reported by Bakkali *et al.* 1997 and Rout *et al.* 2001. Cultures *in vitro* depended on the iron concentration in the culture medium. Regenerated shoots were rooted on a hormone-free half-strength Murashige and Skoog medium (½ MS) before transfer to greenhouse conditions. Present study has suggested that *in vitro* methods can be used for mass multiplication of selected germplasm through seeds as well as nodal bud explants. It is also possible to conserve germplasm of *L. inermis* for breeding high dye yielding strains. The use of MMS full strength and ½ strength medium with different combinations of cytokinins for the induction and multiplication of shoots derived from apical and axillary meristems are essential for mass multiplication of shoots from callus as well as from proliferation of nodal buds.

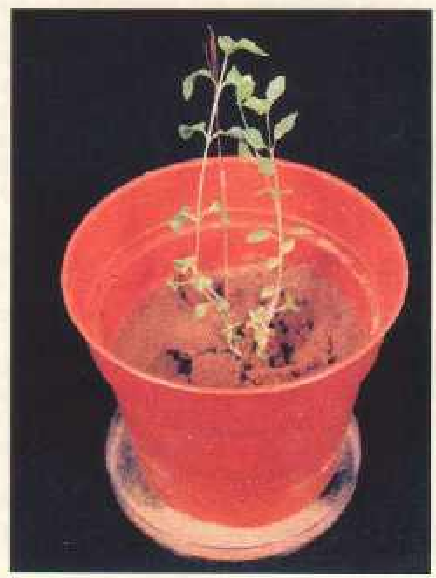

Fig. 5. Establishment of *in vitro* grown plants in pot.

The regulatory action of BAP in combination of KN helped the *in vitro* shoot induction and multiplication in many plant species (Raj Bhansali and Arya, 1978). The maximum shoot induction and multiplication was observed both in apical and axillary meristems of seedling explants cultured on MMS medium supplemented with 1 mg/l BAP, 0.5 mg/l KN and 0.1 mg/l NAA. At higher concentrations of BAP or KN, the rate of shoot proliferation declined. The axillary buds produced more number of shoots than the apical tips. Seed explants were better in morphogenetic potential than nodal bud explant tissues but leafy shoots were stouter from nodal segments. Similar results were reported in *Tecommella undulata* (Raj Bhansali, 1993), *Prosopis cineraria* (Ramawat and Nandwani 1991) *Zizyphus* (Rathore *et al.*, 1992) and *Plumbago zeylanica* (Rout *et al.* 1999). Raj Bhansali and Arya (1978) also reported that BAP proved superior to other cytokinins for multiple shoot induction of many *Citrus* species. Inclusion of auxins in the culture medium did not help in shoot multiplication. Prolonged culture on the proliferation and multiplication media resulted in the blackening of the basal ends of the developing shoots may be because of production of dye in old cultures. The results are consistent with earlier reports indicating cytokinins and auxins affect shoot multiplication in other plants using shoot tip or axillary bud explants (Raj Bhansali, 1990 and 1993, Rout and Das 1993). The results showed that the number of shoots per culture was increased in continuous light. The rate of multiplication was high on continuous subcultures after 25 days. This might be due to the better adoption of *in vitro* grown shoots and induction of high regeneration ability (Zimmerman 1985, Raj Bhansali *et al.*, 1991).

The well elongated shoots rooted maximum on MMS basal salts without auxin and cytokinin but with 2% sucrose. The rooting ability was reduced with the increase in the concentration of NAA in the medium. The percentage of shoots forming roots and time taken in rooting significantly varied with different type of explants and germplasm. The rooted plantlets were established in the pots. *In vitro* protocol for mass multiplication of *L. inermis* by selecting type of explants tissues, manipulating the nutrient salts of MMS, growth regulators and culture conditions have been standardized. Bakkali *et al.* (1997) have determined lawsone in the plant material grown in tissue cultures using a new HPLC method. This dye can be used for staining protein in polyacrylamide gel electrophoresis (Ali and Syeed,1990). They showed that lawsone accumulation *in vivo* is restricted to the aerial part of the plant. However, hairy root cultures established by a co-culture method using leaf segments of *L. inermis* and *Agrobacterium rhizogenes* NCIB 8196 have produced 0.13 per cent dry weight lawsone content which is much lower than field grown plants. The production of lawsone and tannin production has been reported in hairy roots tissues incubated in the dark and cultured in ½ MS or full MS media (Bakkali *et al.*, 1997a). This also suggests the possibility of inducing lawsone and tannin biosynthesis in root cultures by manipulating media constituents and cultural conditions. Thus, *in vitro* methods could prove excellent system for the study of biosynthetic pathways of 2-hydroxy-1,4-naphthoquinone and mass multiplication of selected superior germplasm of henna. These biotechniques will further facilitate in better understanding and enhancing lawsone contents which will ultimately help in development of de novo germplasm having more number of dye molecules.

References

Ali, R. and S. A. Sayeed, 1990. A plant dye from *Lawsonia inermis* for protein staining after polyacrylamide gel electrophoresis. *Electrophoresis*, 11:343-344.

Bakkali A. T., Jaziri M., Foriers A., Vander Heyden Y., Vanhaelen M. and Homès J.1997. Tannin production in hairy root cultures of *Lawsonia inermis*. *Journal of Plant Physiology*, 151: 505-508.

Bakkali A. T. Jaziri M., Foriers A.,Vander Heyden Y.,Vanhaelen M. and Homès J. 1997a. Lawsone accumulation in normal and transformed cultures of henna, *Lawsonia inermis*. *Plant Cell, Tissue and Organ Culture*, 51:83-87.

Ideada, K., D. Teshima., T. Aoyama, M.. Satake and K. Shimomura, 1988. Clonal propagation of *Cephaelis ipecacuanha*. *Plant Cell Rep.*, 7:288-291.

Murashige, T and F. Skoog 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant*, 15:473-497.

Raj Bhansali, R. 1990 Somatic embryogenesis and regeneration of plantlets in Pomegranate. *Annals of Botany*, 66:249-I253.

Raj Bhansali, R. 1993. Bud culture of shoot multiplication and plantlet formation of *Tecomella undulata* (Rohida) woody tree of arid zone. *Tropical Science*, 33:1-8.

Raj Bhansali, R. 1995. A manual of Plant Tissue Culture. Department of Biotechnology and Indian Council of Agricultural Research, Joint Publication, Jodhpur, pp.1-122.

Raj Bhansali, R. and Arya, H.C. 1978. Tissue culture propagation of Citrus trees. *Proc. Int. Soc. Citriculture*, 135-140.

Raj Bhansali, R., Driver, J. A. and Durzan, D. J.1991. Adentitive embryogenesis and plant regeneration from rescued peach embryos. *Indian Journal of Experimental Biology*, 29:334-337.

Ramawat, K. G. and Nandwani, D. 1991. Propagation of *Prosopis* species: Problems perseverance and perspectives. *Annals of Arid zone*, 30:247-258.

Rathore, T. S., Singh, R. P., Deora, N. S. and Sekhawat, N. S. 1992. Clonal propagation of *Ziziphus* species through tissue culture. *ScientiaHort*, 51: 165-168.

Rout,G.R, Das, G, Samantaray, S and Das, P. 2001. *In Vitro* Micropropagation of *Lawsonia inermis* (Lythraceae). *Rev Biol Trop.*, 49:957-63.

Rout, G.R and P. Das 1997. *In vitro* organogenesis in ginger (*Zingiber officinale* Rosc.). *J. Herbs, Spices and Medicinal Plants*, 4: 41-51.

Zimmerman, R.H. 1985. Application of tissue culture propagation to woody plants. pp. 165-177. *In*: R.H. Henke, K.W.Hughes, H.J. Constantin and A. Hollaender (Eds.). *Tissue Culture in Forestry and Agriculture*. Plenum Press, New York.

Participatory Improvement of Henna

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Since the first domestication of wild plants about 12,000 years ago, farmer plant breeders have been responsible for the development of thousands of crop varieties in hundreds of species (Harlan, 1992). Plant breeding as a specialized activity began about 200 years ago in industrial countries. Modern professional plant breeding developed in the early part of the 20th century (Simmonds, 1979). The emphasis of most of the plant breeders has typically been on developing a relatively small number of genetically more uniform varieties adapted to wide, uniform and relatively low stress conditions with high yields and stability. Farmers' varieties are characterized by narrow geographical adaptation to marginal (relatively high stress and variable) growing environments, and high yield stability in those environments (Cleveland and Soleri, 2002).

Plant breeding by scientists has become increasingly separated from plant breeding by farmers (Simmonds, 1979). The distance is especially great in the case of small-scale farmers planting in marginal growing environments with limited access to external inputs. Participatory approach proposes to reverse the historical trend of separation between farmers and plant breeders. Plant breeding with farmers is a way to both increase yields and other desirable production components in marginal environment, while at the same time supporting *in situ* conservation of crop genetic diversity (Welzien *et al.*, 2000).

Participatory Crop Improvement has developed over the past decade as an alternative and complementary breeding approach to Formal Crop Improvement (Almekinders and Elings, 2001). The genetic aspects of participatory crop improvement can be divided into participatory varietal selection and participatory plant breeding, former dealing with evaluation of varieties where as the latter with the segregating populations. Broadly speaking, participatory plant breeding is the development of a collaborative plant breeding programme involving breeders and farmers, marketers, processors, consumers, and policy makers. It involves close farmer-researcher collaboration to bring about plant genetic improvement within a species and farmers are active partners implying empowering the farmer. The goal is to increase productivity and profitability of crop production through the development and enhanced adoption of suitable, usually improved varieties, besides building farmer skills to enhance farmer selection and seed production efforts. The results from participatory plant breeding are likely to be more effective in risk prone areas. It not only helps in better understanding of needs of the farmers and traders through interaction, but also ensures better performance and easy adoption because of selection under real situations from much larger populations and active involvement of farmers in making the selections.

Genotype x Environment interaction is always an important issue in plant breeding. Selections made at the site of farmers with their active involvement, analyzed in the laboratory for their economic content and integration of this feedback for developing populations for that specific region are certainly expected to be more productive. In risk prone areas, and unique but important minor crops that are not the focus of formal plant breeding efforts, the development of populations or heterogeneous material through participatory plant breeding may be the ideal approach. Henna is a candidate species for this breeding method as it is mainly under rainfed cultivation in arid fringes of district Pali (Rajasthan). The approach is worthwhile in henna because of the following reasons:

- There are limited germplasm collections of henna available in the country.
- Most of the cultivation is concentrated in small pocket of Pali district in Sojat Tehsil where farmers have been growing henna for last 50-60 years continuously and conserving the local biodiversity.
- Large even aged uniform populations of the perennial shrub (henna) are available.
- Over years traders and farmers know better fields and regions within this area. For example our interaction with Milan Mehndi, the leading processor of henna leaves, revealed that henna from village Kali Beri is of better quality.
- Farmers have been harvesting the same field for many years and know the plant type and their behaviour very well.
- Uniform populations spread over hectares, a close knit society of producers and traders, a separate market devoted only to marketing of henna leaves and experience of farmers on this ratooning shrub provides unique opportunities to undertake participatory plant improvement programme.
- This rainfed crop is being grown in limited area due to unique agro-ecological conditions. Undertaking improvement programmes at research stations placed away from this location, will need extra efforts, and is likely to be less productive, because of variations in environmental conditions at station and on-farm. It will always be a dream to raise such stands of uniform even aged populations as can be seen in the farmers fields. Even best on station efforts may not compensate for G x E interaction component.
- Farmers growing this crop are involved in all aspects and understand needs and behaviour of the crop under variable conditions. It needs no emphasis that each year in arid and semi-arid regions is unique in the sense that rainfall pattern and amount is seldom repeated and dry spells are not infrequent.
- Farmers have developed their own methods of water harvesting like bunding the fields and use traditional tools for weeding, hoeing, etc. Selections with active involvement of the farmers under the real farming situations are likely to be better adopted to the situations existing in these fields.

In our efforts to initiate participatory plant improvement programme in henna, the first step was to establish link with farmers, traders and industrialists, interact with them and understand their needs (Fig. 1). Information on sites that are considered to yield better crop was collected from the traders and industrialists. Interaction with the farmers revealed the presence of two ecotypes of henna in their fields, one having vigorous growth and broad leaves referred as *mehndi* and the other having narrow leaves, pointed primary branches and seldom flowering (referred as *muraliya*). In some fields there were mixed population of both the ecotypes, whereas a few farmers had raised separate stands of *muraliya* as it is believed that this ecotype has more dye. However, due to small leaf size, low yield and spiny tips of branches that make the harvesting difficult, the farmers and skilled workers did not prefer this ecotype. Few farmers during interactions also differentiated mehndi into two maturity groups and actually showed some of the plants whose basal leaves had fallen earlier than the other plants. Such plants were having slightly erect branching and were mentioned as *khajuriya*. Even though farmers wish to have quality seedlings but our observations were that only random seed was collected. Even though farmers' preference was for late and minimum flowering plant types (because in Sojat henna is being grown only for leaf), there is unconscious wrong selection. Maximum seed in seed lots collected at random is contributed by the early and heavy seed producers. Even though farmers will prefer to have late flowering and less seed producing genotypes, but majority of the plants from the randomly collected seed lots will have the opposite attributes. Further, the people involved in raising nursery are doing this specific business only and may not be interested in collecting the seeds from selected plants that are less flowering and late maturing. Every farmer desired to have quality seedlings but no such mechanism, established seed orchard or variety was available in the market. Major cost of henna cultivation is during transplantation and about 50 per cent of the cost is that of the seedlings alone.

Henna once established is ratooned for 15 to 20 years or even more. Hence poor plants once established in the field will continue to give poor yield year after year for 2 to 3 decades. Thus it is utmost important to make genetic improvement in this perennial species.

The plantations existing in and around Sojat represent the land races and selections made by the farmers over years. The results of the selections made by our team in collaboration with farmers and skilled labourers involved in harvesting the crop are presented in Table 1. Six plants were selected from each field of the ten farmers and data was recorded on height, spread, etc. Leaf samples and cuttings/seed was also collected from each of the plant separately. Lawsone content (mean of six plant samples) in each field are also presented in table 1.

Visits were undertaken in October 2004 to farmers' fields just before the crop harvest. The approach has been to make selections through active involvement of the farmers, collect leaves as well as seed/cuttings of these plants. The leaf samples collected from individual selected plant were analyzed for lawsone content, so as to make selections out of the selected plants using both visual parameters of farmer and researcher and the actual non-visible economic parameter of dye content. The plant type preferred by the farmers was the one having broad leaves, good growth, late maturing (i.e. without shedding of lower leaves) and having no or minimum flowering/fruiting. The cuttings (five of each plant), seed (wherever available) and leaf samples from individual selected plant in consultation with the farmer/field workers were collected from sixty plants (six each from the ten fields).

Fig. 1. Scientists interacting with farmers at their field

The height in the sixty selected plants ranged from 100-230 cm; plant spread varied from 68 to 234 cm; and number of tillers ranged between 16 and 37 with mean values of 181.2, 154.0 and 23.5 in the respective order. Plant populations keep on reducing over years and in some pockets few plants perform much better and dominate. These have much better morphological characters than rest of the populations. Of these sixty plants, only fourteen were having medium flowering/fruiting and the remaining 46 had only little flowering/fruiting. Lawsone content in the sixty plants ranged from 1.60 to 2.80 per cent. Only twelve plants had lawsone content less than 2.00 per cent and thirteen plants had more 2.30 per cent lawsone content. As a matter of fact, only five plants had lawsone of 2.4 per cent or more. Majority of the plants (35) had lawsone content between 2.00 and 2.30.

In the ten fields, the average age of plantation was 20 to 30 years in eight fields and the other two had 8-12 year old

Table 1. Morphological characteristics and lawsone content in the six plants selected from the fields of each of the ten farmers in and around Sojat Road through participatory approach

Name of farmer	Village	Approx. age of plantation	Plant height (cm)	Plant spread (cm)	Tillers/ plant	Lawsone (%)
Nena Ram	Nehda Bera	8-10	176.7	110.0	25.8	1.90
Nema Ram	Sojat Road	10-12	148.3	138.8	25.3	2.09
Chena Ram Mali	Sojat Road	20-25	193.8	181.7	29.7	2.13
Deva Ram Seervi	Sojat Road	20-25	181.7	145.4	22.3	2.13
Gora Ram	Siriyari Phanta	25-28	162.5	115.4	20.5	2.06
Raja Ram Mali	NagaBeri	25-30	195.2	180.6	23.7	2.17
Mohan Ram Mali	Naga Beri	15-20	187.8	169.6	19.2	2.12
Kana Ram	Naga Beri	25-30	181.2	153.4	22. 7	2.24
Hema Ram	Naga Beri	25-30	181. 7	160.1	20. 7	2.14
Skilled labour	Naga Beri	20-25	204.5	185.4	25.5	2.37
Overall Mean			181.2	154.0	23.5	2.13
S.D.			25.7	35.1	4.8	0.22

plantation. The average height of the plants in the individual field varied from 148 to 195 cm, spread varied from 100 to 181 cm and mean number of tillers ranged from 19.2 to 29.7. Lawsone content varied from 1.90 to 2.37 per cent.

As mentioned earlier, during our interaction with industrialists, we were told that leaves from Kali Beri area near Sojat are of better quality. Of the sixty samples collected, thirty were from this area whereas the others were from other adjoining villages of Sojat. The perception of the traders was clearly reflected in our analysis of lawsone content. The mean lawsone in 30 samples from Kali Beri area was 2.21 per cent as compared to only 2.06 from rest of 30 plants collected from rest of the area. The plants having highest lawsone content were also from Kali Beri area.

The purpose of the approach was to select the best plants as per farmers' perception and further select out of these plants on the basis of lawsone content. The results show that at 20 per cent selection, i.e., selecting only 12 plants out of 60, the lawsone content was 2.43 per cent as compared to that of 2.13 per cent of the sixty plants. The change in height, spread, tillers and the lawsone content at different selection intensities is presented in Table 2. The rooted cuttings of selected plants will be used to establish the clonal seed orchard and seed produced will be evaluated at farmers' field.

Table 2. Plant height, spread, tillers and lawsone content at different selection intensities on the basis of lawsone content

Selection (%)	No of selected plants	Height (cm)	Spread (cm)	Tillers /plant	Lawsone (%)
100	60	181.2	154.0	23.5	2.135
80	48	183.9	160.4	23.7	2.214
60	36	188.4	165.7	24.0	2.273
40	24	188.3	168.1	24.0	2.336
20	12	192.3	178.4	23.7	2.430

Most of the henna fields are rainfed in Sojat and surrounding areas where only one crop is harvested during October. There are very few irrigated fields where farmers are able to take second crop. The quality of henna from irrigated areas is considered to be poor. Even during low rainfall years, very few farmers have the facility for supplemental irrigation for the main season crop of July-October. Crop of all the 10 farmers involved in participatory breeding was rainfed.

The correlations coefficients of morphological traits and lawsone content are presented in Table 3. Lawsone content had significant and positive association with plant height and spread with number of tillers, though positive, was non-significant. The associations suggest that plants having better growth, which is a reflection of better root system, provide better lawsone. It may be interesting to see the effect of spacing and age of plantation on lawsone content. There are various reports suggesting that higher temperature, low moisture and stress results in higher lawsone content; henna can tolerate salinity and various other adverse conditions; and cannot survive at very low temperatures approaching freezing point. There is need for quantification and screening of various genotypes under such conditions for developing location specific cultivars. As expected on the basis of synchronized growth, the association of plant height, spread and number of tillers was significant.

Table 3. Correlation of different traits (n = 60)

Characteristics	Height	Spread	Tillers/ plant	Lawsone (%)
Height	-	0.728**	0.291*	0.288*
Spread		-	0.323*	0.486**
Tillers/plant			-	0.146
Lawsone (%)				-

* $p < 0.05$, ** $p < 0.01$.

There are number of examples of participatory plant breeding in different countries, especially for stress conditions. Gypmantasirii *et al.* (2003) from their experience on farmer participatory plant breeding for rainfed rice in Thailand have stated that the modern high yielding rice varieties, being developed and selected under more favourable station conditions, are not always suitable under rainfed environment. In participatory research, farmers' priorities are better understood and participatory plant breeding approach has increased adoption and economic benefits from adoption. As per Banziger and Cooper (2001), participatory plant breeding has been suggested as an effective alternative to formal plant breeding as a breeding strategy for achieving productivity gains under low-input conditions as demonstrated by comparison of formal plant breeding and participatory plant breeding in tropical maize and wheat. Participatory Crop Improvement principally aims at more effectively addressing the needs of farmers in marginal areas in developing countries (Almekinders and Elings, 2001). The studies undertaken in different crops in rainfed areas suggest that the participatory approach may be more appropriate, cost effective and more productive.

References

Almekinders, C.J.M. and Elings, A. 2001. Collaboration of farmers and breeders: Participatory crop improvement in perspective. *Euphytica* 122: 425-438.

Banziger, M. and Cooper, M. 2001. Breeding for low input condition and consequences for participatory plant breeding-examples from Tropical maize and wheat. *Euphytica* 122: 503-519.

Cleveland, D.A. and Soleri, D. 2002. Introduction: Farmers, Scientists and Plant Breeding: Knowledge, Practice and the possibilities for Collaboration. In *Farmers, Scientists and Plant Breeding* (eds. D.A.Cleveland and D. Soleri) CAB International 2002.

Eyzaguirre, P. and Iwanaga, M. 1996. Proceedings of workshop on participatory plant breeding 26-29 July, 1995 Wagenin, The Netherlands. *IPGRI publication.*

Gypmantasirii, P. Limnirankul and Muangsuk (Eds). 2003. Integration of farmer participatory plant breeding for rainfed lowland rice improvement in North and Northeast Thialand, pp.1-88.

Harlan, J. 1992. Crop and Man. 2nd Edn. *American Society of Agronomy*, Madison, WI, 284 pp.

Simmonds, N.W. 1979. The Social Context of Plant Breeding. *Plant Breeding Abstracts* 60: 337-341.

Weltzein, E. 2000. Supporting farmers' genetic resource management: Experience with pearl millet in India. In: C. Almekinders & W.de Boef (Eds), *Encouraging Diversity. The Conservation and Development of Plant Genetic Resources*, pp. 189-193. Intermediate Technology Publications, London.

Henna Marketing, Processing and Trade in India

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Commercial henna is a natural dyestuff prepared from its dried leaves and used as cosmetic for application on hands during festivals and religious occasions. The dyeing of hair to improve its lustre is also one of the important uses of henna powder. The Sojat area in Pali district of Rajasthan is worldwide famous for best quality henna production. The henna leaves are transformed into powder form following different steps in the processing industry. Besides field plantation, it is also cultivated in few other parts of the country as a hedge and also for production of flowers for extracting oil. The essential oils extracted from henna flowers are used in perfume industry. Sojat is the major centre in the country for marketing of dried henna leaves and its processing. The henna processing industry generates non-farm employment through preparation of packaging material for henna leaves (Fig. 1), transportation of leaves to factory and in different operations like cleaning, grinding and powder packaging, etc. (Khem Chand *et al.*, 2003). The demand of henna powder and finished products is growing in the world in general and Middle East & Western world in particular due to growing fear of harmful health effects of synthetic dyes (Korwar and Pratibha, 1998).

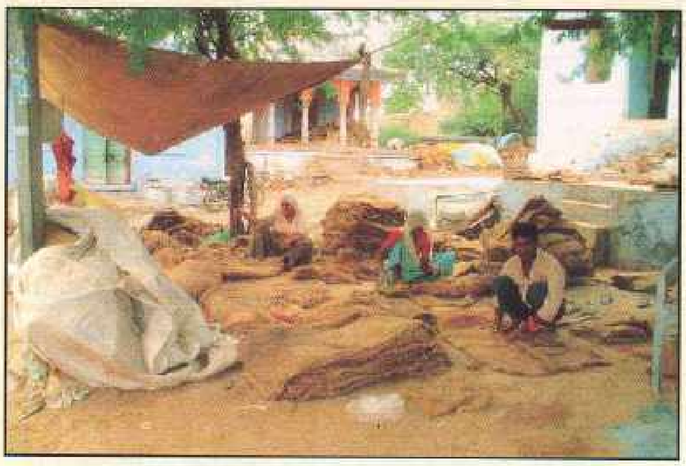

Fig. 1. Preparation of jute bags in Sojat market for filling henna leaves

Marketing of Dried Henna Leaves

The Market: Sojat city Sub-Mandi, that falls under jurisdiction of Sojat road Agricultural produce market i.e. Main Mandi, is one and the only regulated market in the country meant solely for trading of henna leaves (Fig. 2). Though henna is also marketed in small quantity in Bhawani mandi (Rajasthan) but eventually it comes to Sojat for sale and processing. According to the officials of this regulated market about 90 per cent of henna leaves produced in Rajasthan is marketed at this mandi. The remaining 10 per cent is sold directly to processing industry. The produce from adjoining states Gujarat, M.P. and other districts of Rajasthan (mainly from field boundary plantation/ hedges) is also marketed in this mandi and processed in Sojat city itself.

Facilities in the market: Though under normal weather conditions harvested henna leaves are not perishable but if exposed to rain or direct sunlight the quality deteriorates. So to protect henna produce in this sub-mandi yard there is a significant storage facility in the form of open tin-sheds having cemented platform of about two and half feet height aboveground which are fully utilized by the farmers/ middlemen. The market has around 30 commission agents/ registered traders and lot of brokers ('dalal') who facilitate farmers and mandi officials to carry out smooth trading of henna leaves. Over the years due to increasing production of henna, facilities created are not sufficient and sometime leaves are spoiled due to open storage. So there is a need for further expansion of facilities in mandi like more number of sheds, guest house for farmers, bank, etc.

Fig. 2. Transaction of henna leaves in Sojat henna mandi yard

Marketing channels: The main marketing channels used by farmers for sale of dried Henna leaves are:

1. Farmer (Producer) → Local middlemen → Mandi → Industries (Fig. 3)
2. Farmer (Producer) → Mandi → Industries
3. Farmer (Producer) → Industries

Fig. 3. Transportation of henna leaves from mandi to factories

About 70 per cent of henna leaves produced is marketed through the channel number one (mentioned above) and of the remaining around 20 per cent is marketed through channel two listed above. Rest of the produce either reaches directly to the processors or disposed off locally through retail sale. Since dried henna leaves need more space for storage and every farmer cannot create this, so some farmers almost in each and every village (having significant area under henna) act as middlemen and purchase the produce from other farmers and either sell it in mandi when having sufficient volume to load a truck or store it in the expectation of price rise in the market.

Quality assessment of henna leaves in market: The price of henna dry leaves in the market is governed by quality of leaves, which is ascertained on the basis of leaf weight, leaf thickness, aroma, colour, and origin, etc.

The first hand impression is that all these methods are non-parametric one but there are no other standard methods available to get rid off these and make the trading more authentic and reliable. This is one of the biggest grievances of farming community because accuracy of the quality assessment is totally based on the experience of the traders and it is always questionable. For example in case a farmer brings produce spoiled by rain the trader gives very low prices (as low as 10-15 per cent of normal rates) for this without considering the extent of damage in the quality. The analysis of lawsone content in the lab suggests that there is only marginal decrease in lawsone content. As the crops primary economic component is the lawsone content, it will be worthwhile to assess the crop on the basis of dye content. At present very simple, quick, accurate and cheap spectrophotometric method of lawsone estimation as described by Pratibha and Korwar (1999) is available.

Trends in henna leaf marketing and price: The trend line in the figure 4 indicates that in recent years the trade of henna leaves in the Sojat city regulated market is continuously increasing. In the year 1995-96 the trade of henna leaves was 10264 tons which increased to around two and half times in the year 2003-04 (24744 tons) with a significant annual compound growth rate of 9 per cent. In terms of rupees the trade was 20.53 crores with average price of Rs. 2000 per quintal in the year 1995-96 which increased to Rs. 65.37 crores with average price of Rs. 2642 per quintal in the year 2003-04. In general during low production years prices of henna leaves are higher than good years but it fluctuates to a wide range hence the farmers only seldom fetch good price for their produce due to inadequate market information or inability to store for long time. The produce of the region is processed at Sojat and there are no reports of glut in production of henna leaves. The produce of particular season is normally processed before the next crop as storage beyond one year and moisture conditions affect the quality of henna.

Processing of Henna Leaves

The processing industry: It is mainly concentrated in Sojat city of Pali district (Rajasthan). Commercial henna leaf processing in the city began in 1957. Initially dried leaves were powdered using stone grinders in traditional flour-mills. For better quality of grinding the size of the emery stones in these mills were increased and the larger sized emery stones used in such burr mills were especially ordered from Kuchaman (Nagaur district). As the volume of processing increased beyond the capacity of these stone burr mills, in early 1980s, processing of henna leaves was also started in the hammer mills with much higher turnover. However, the powder from these units was found to be inferior in quality being blackish in colour compared to the greenish colour powder obtained from the burr mills. It was found to be due to the higher temperature conditions produced during processing in the hammer mills. To overcome this limitation, several improvisations were tried in these hammer mills. By 1985 the original cast iron hammers were replaced by stainless steel hammers (initially fabricated at Kanpur) after trials with hammers made from copper and then aluminium in between. Further, cyclone air-cooling towers were introduced to control build-up of temperature during processing that lead to blackening of the powder. The henna processing and marketing company, the M. M. Sojatwala Co., at Sojat was the pioneer in the introduction and refinement of the hammer mill units. Finally, for greater control and efficient processing of leaves, the pulverizers, in use in the limestone industry of Sojat, were adopted. This development was again due to the efforts of above manufacturer. Presently while the major industries employ the pulverizer units for henna processing, all above types of henna processing units are in operation simultaneously at Sojat.

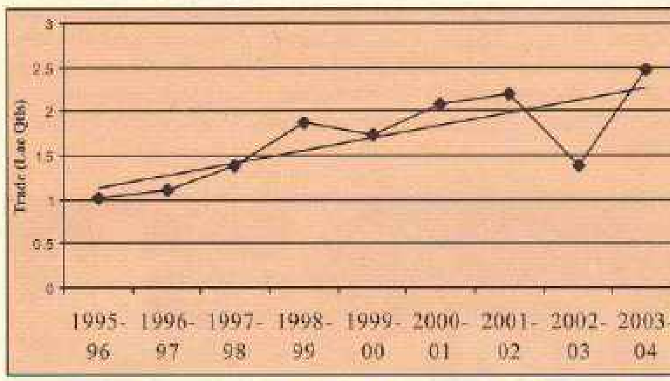

Fig. 4. Recent Trends in henna leaves trade in Sojat city

Development of henna processing industry in Sojat :

- ***1957:*** *Commercial processing of henna powder started*
- ***1962:*** *Special burr stone mills began to be installed for producing henna powder* (Fig. 5)
- ***1980*:** *Introduction of hammer mills in henna leaf grinding and processing*
- ***1980-85:*** *Improvisations in the hammer component of the units for improving quality of henna powder*

Fig. 5. Grinding stones piled up outside the henna factory

- ***1987:*** *Cyclone air-cooling towers introduced in the processing units for temperature control*
- ***1990's:*** *Introduction of pulverisers*

There are around 180 henna processing units in Sojat (Trivani Kumar, 2004). It provides gainful employment to more than 3000 persons working in this industry. In addition to these units around 50 trading companies are also working in the city. Faridabad city in Haryana also has about 20-25 processing units but comparatively more quantum of henna is processed in Sojat. In general semi processed henna leaf is procured by processing industry at Faridabad city. The henna processing in the units starts from Diwali (Sept. - Oct.) with the arrival of the main harvest of kharif season (80 per cent of total production). The processing units work day and night between Diwali and Holi i.e. Sept. - Oct. to March- April. Thereafter until the next growing season units are under operation during daytime only. And during the crop growth season the units are mostly idle and repair and maintenance work is carried out.

Procurement of raw material: The major source of raw material for the processors is henna sub-mandi, Sojat city, wherefrom one can purchase the material of desired quality and quantity through open auction method. The quantity of leaf purchased by an individual processor at a time depends upon the processing capacity of his unit and market demand. Whenever processing industry receives big export orders, the procurement of raw material i.e. henna leaves increases in the mandi and prices of henna leaf move upward. During procurement process the processors assess the quality of raw material based on leaf weight, thickness, aroma and visual colour. In addition importance is also given to the origin of produce (state/ region of production) and whether the produce is from rainfed or irrigated fields or from hedges.

Stages in henna processing: Henna leaves pass through different stages of processing viz., cleaning, leaf cutting, grinding, screening, packaging, etc. before conversion into powder to be used by the consumers or other industry as intermediary input. The various steps in processing are discussed in brief hereunder:

- *Cleaning*: The dry henna leaves purchased in the market are cleaned before further processing. Any soil material present is separated out by passing the leaves through a rotating perforated drum (Fig. 6) and the cleaned plant material is blown out and collected. Thereafter fruiting stalks and other branches pieces present along with the leaves are removed in a similar unit with winnowing

Fig. 6. Cleaning of henna leaves in a processing unit

process. During this process clean leaves are collected at a distance away from the heavier stalks, fruits and even stones which gather near the outlet.

- *Leaf cutting/size reduction*: The whole leaves are put through a shredding machine that cuts down the leaves into smaller pieces for easier transportation and movement (Fig. 7 & 8).

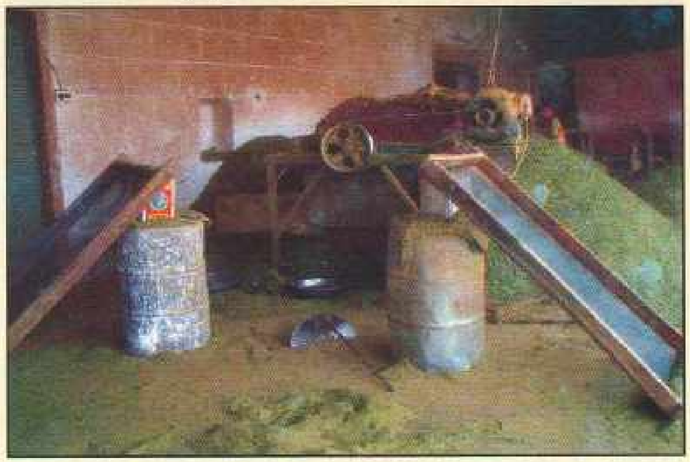

Fig. 7. Crushing of henna leaves in a processing unit

- *Grinding*: The shredded leaves are than fed to grinding machine / hammer mill/ pulveriser for converting into powder of desired particle/ mesh size.
- *Screening*: Screening out the ungrounded fibre pieces in another aerated rotating drum device further refines the powder obtained (Fig. 9). The final ground powder of highest purity is collected and sent for packaging.

Fig. 8. Filling of bags with crushed henna leaves

- *Packaging*: The powder is packed in polythene packages of different size and quality as per requirement of buyers or demand in the market and it is also used as intermediary input for other herbal products (Fig.10 & 11).
- During processing there is loss of 12-18 per cent depending upon the quality of leaves. Most of the wastage is due to seeds, branches, soil particles and some loss is there during grinding and final processing. The average cost of leaves is around Rs 25 per kg and operational cost for its grinding, packing, etc is about Rs 10. The bulk selling price of henna powder varies from Rs 40-55 per kg. The prices are, however, affected by

the rainfall pattern that influences the growth and also international demand that is affected by production in other henna producing countries.

Fig. 9. Pulverisation of henna leaves to powder

There are hardly any units at Sojat involved in value addition in terms of mixing compounds for obtaining different shades of henna or preparation of black henna which is a combination of henna powder and para-phenylenediamine. Henna produced at Sojat is generally of superior quality. Sometimes leaves from other plants of the region like those of *Cassia* spp., *Prosopis* spp are mixed. Such produce is either consumed in local market at lower prices or at times is exported as neutral (used in burial rites?) henna as per demand.

Fig. 10. Mechanical Packaging of henna powder by women

Trade of Henna

The products: There are 153 manufacturers, exporters and suppliers involved in trading of different henna based products in the country (www. Indiamart.com). An estimated quantity of 35000 tons of henna powder was produced during the period 2003-04 by the processing industry in India. The processing industry in Sojat mainly produce henna powder and it is further used either in powder form by consumers or manufacturing of different henna based products by other small scale or large industries. The henna processing and other industries that use henna powder as intermediary input, produce different products viz. hair dyes, herbal hair conditioners, henna oil, plastic cones, henna paste tube, hair shampoo, cream, aroma therapy products, powder and paste formulations for temporary tattooing of palm and other body parts. About 80 per cent of the powder is used in manufacturing hair dying and conditioning products. Henna based herbal products are used for dying and conditioning of hair and they contain besides henna powder other herbs like Bringhraj, Brahmi, Aonla, tea, Shikakai, etc.

Fig. 11. Automatic packaging of henna powder

Marketing channel of processed henna: The main marketing channels used by processors for sale of processed henna powder are:

1. Processor → Wholesaler → Retailer → Consumer
2. Processor → Retailer → Consumer
3. Processor cum retailer → Consumer

About 50 per cent of the henna powder produced in the processing industry is further sold through channel number one mentioned above. The wholesalers in different cities procure henna powder directly from the industry at Sojat and Faridabad and further sell it to retailers. The consumers get their required quantity from the retailers. The remaining 50 per cent of the powder is sold through retailer or directly to the ultimate users. The other henna based industries either get their required henna powder from processing industry or through brokers in Sojat and Faridabad. Similarly export of processed henna is also done by processors or brokers or by other industries that uses powder as intermediate inputs for manufacturing of other henna based products.

References

Khem Chand, B.L. Jangid, and S.S. Rao 2003. Henna: A potential source of non-farm employment and economic development in arid fringes. *Agricultural Economics Research Review,* Conference issue, pp. 179.

Korwar, G.R. and G. Pratibha 1998. Henna for Drylands. *Intensive Agriculture*, March-April, pp. 20-21.

Pratibha G. and Korwar G.R. 1999. Estimation of lawsone in henna (*Lawsonia inermis*). *Journal-of-Medicinal-and-Aromatic-Plant-Sciences.* 1999, 21(3): 658-660.

Trivani Kumar 2004. G.M. District Industrial Centre, Govt. of Rajasthan, Pali (Personal communication).

www. Indiamart.com (visited on 2.11.2004).

Economic Scrutiny of Henna Cultivation

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In India the semi-arid part of Rajasthan has significant area under commercial henna cultivation. Pali district of this part of Rajasthan has around 95.26 per cent (Anonymous, 2002) of state's henna area and Sojat tehsil of this district is worldwide famous for best quality henna production. Both Sojat and Marwar Jn. tehsils of the Pali have more than 93 per cent of henna cultivation area of the district (Table 1).

Table 1. Tehsil-wise area under henna in Pali district (2000-01)

S. No.	Tehsil	Area (ha)	per cent of district
1.	Pali	189	0.62
2.	Bali	8	0.03
3.	Desuri	61	0.20
4.	Marwar Jn.	8479	27.87
5.	Sojat	19844	65.24
6.	Raipur	1237	4.07
7.	Jaitaran	487	1.60
8.	Rohat	108	0.36
9.	Sumerpur	5	0.02
	Total	30418	100.00

Source: District Land Record Office, Pali

Commercial henna cultivation in arid fringes of Rajasthan was scrutinized as an economically viable agricultural enterprise by the authors through a sample survey study (1999-2004) among the farmers of Sojat and Marwar Jn. tehsils of Pali district.

Cropping Pattern of Henna Growing Farmers

Henna farmers have major portion of their land under henna cultivation. Farmers allocate as high as 68 per cent area under its cultivation (Khem Chand *et al.*, 2002). In addition to henna, cropping pattern includes cereals (wheat, pearl millet, sorghum, etc.), oilseeds (sesame and rape-mustard), and cash crops (vegetables, fennel, etc.). The pulse crops did not receive a significant area in either season (rabi/kharif). It may be due to the fact that the major pulse crops in the area (moongbean and mothbean) are cultivated in *kharif* season, which is dominated by henna. The sorghum is mainly cultivated for fodder purpose while barley is both for fodder and concentrate feed for animal rearing (bovines), which forms an important enterprise in the study area. Total cropped area in *rabi* was lower than *kharif* season, since in *kharif* most of the crops cultivated are rainfed hence farmers try to cultivate maximum possible area, but in *rabi* season cultivation of crops is constrained by availability of irrigation water in the wells due to depletion of groundwater.

Fixed Investment Incurred by Farmers

Fixed investment on a farm consists of expenses on items of permanent nature. These resources do not wipe out with one time use. Authors found an average fixed investment of Rs. 36,921 on the farms of henna growing farmers and three-fourth of this was accounted by farm machinery and implements alone. The investment on well and engine/ pump set was 14.81 and 4.39 per cent, respectively. Comparatively low investment on wells is due to the fact that in most cases 8-10 farmers have their share in one well. Every individual farmer does not invest on purchase of big farm machinery like tractors due to heavy initial investment. The use of farm machinery on hiring basis is increasing in the area. In henna cultivation farmers require tractor for field preparation and most of the farmers in the area complete this operation by hiring tractors.

Plantation and Establishment Cost

Henna is perennial shrub crop and farmers have to invest a lot in its plantation and establishment. Some farmers though interested in its cultivation are not able to cultivate the same due to initial high investment. Over the years due to increasing awareness among the farmers about henna cultivation the demand for skilled labour and seedlings is increasing in the region and this is pushing the prices of limited skilled labour and quality seedlings in the area. Once established in the field, every year hoeing/ weeding and harvesting operations have to be performed by the farmers.

Farmers, who want to plant henna in their fields, need to prepare for it well in advance as it incurs more expenses then a normal arable crop. At the same time they have to book required quantity seedlings in advance so that supply of quality seedlings in time can be assured. Seedling growers also invest a lot in its raising. They ensure proper supply of water in the field and employ labour for proper maintenance of nursery. In the month of July-August when farmers feel that conditions for henna transplanting are suitable, they transport seedling in their fields. At this time there is a heavy competition among farmers for skilled labour who can perform this operation perfectly and in limited time span. Farmers treat seedlings with chloropyriphos for protection of plants from the attack of termites.

It was found that on an average farmers have to invest an amount of Rs. 25267 (2003-04) for plantation of henna on one hectare area (Table 2). The cost of seedling (47.83 per cent) is an important constituent of the establishment cost, in view of the fact that seedling growing requires assured irrigation facility during the hot summer months of March to June and every farmer cannot afford to grow it; hence the seedling growers try to fetch the maximum benefit from sale of seedling. The henna seedlings are grown only in few pockets of Pali district where supply of quality water is assured. Further there is always demand for good quality seedling which nursery growers are not able to meet, resulting into higher sale price to buyers.

Table 2. Initial cost of plantation and establishment of henna (ha^{-1})

Components	Share in total cost	
	(Rs.)	(%)
Labour	9062	35.86
Seedlings	12086	47.83
Ploughing and related operations	4119	16.30
Total	25267	100.00

The labour cost (35.86%) is also an important constituent of plantation and establishment cost. Due to high demand of skilled labourers for this work (which is to be completed within a period of two-three days) wage rates are generally high during this period.

Recurring Expenses

Once henna is established in the field only hoeing, weeding and harvesting operations have to be carried out every year. Henna requires less care in comparison to arable crops grown in the area because it is not damaged by animals. Farmers generally do not use any fertilizer or plant protection measures for this crop, but in recent years incidence of Caster semilooper (*Achoea janata*), causing damage to henna leaves, has compelled the farmers for random use of pesticides in some farms. During hoeing/weeding and harvesting operations wage rates in general are high in the area since all the farmers want to complete the operation in time.

Table 3. Recurring expenses in henna cultivation (ha^{-1})

Components	Share in total cost (Rs.)	(%)
A. Fixed cost	3032	21.54
B. Variable cost		
Labour	10266	72.92
Transport	172	01.22
Packing	392	02.78
Interest on working capital	217	01.54
Total	11047	78.46
C. Total cost (A+B)	14079	100.00

It was observed that farmers spend an amount of Rs. 14079 for maintenance and harvesting operations per hectare of henna plantation. The labour alone accounted for 72.92 per cent of total recurring cost (Table 3), which was mainly used for hoeing & weeding, harvesting of leaves with tender branches, threshing and packaging operations, etc. The wage rates were found highest during harvesting and related operations, since especially skilled labour is required for the same. The threat of quality degradation of the harvested leaves due to rains also forces the farmers to complete this operation within a minimum possible period, further pushing the wage rates. Attempts by some farmers to harvest the leaves using mechanical harvester to reduce labour cost didn't succeed.

Returns from Henna

Being a perennial crop, henna leaves are harvested every year. The number of times a farmer harvest the leaves depends upon growth of crop. Generally in rainfed fields it is harvested once in a year but in some area where wheat crop is taken with henna in *rabi* season with irrigation, farmer get an additional yield from this crop. On an average farmer in the Pali district in rainfed area get 10.48 quintal dry leaf yield of henna per hectare particularly in good rainfall years (Table 4). The production is highly dependent upon good and timely rainfall as it is a rainfed crop. Sometimes due to rains at harvest time, quality of henna leaves is degraded which means drastically low price of henna leaves in the market. It was established that farmers get average net returns of Rs. 12450 after accounting both fixed and variable cost incurred in henna cultivation. Compared to this Singh and Gupta (1998) reported an average gross return of Rs. 19,086 ha^{-1} during 1995-97 from wasteland plantations of henna in Jodhpur. However, the net profit of Rs. 36,000 ha^{-1} worked out by Kavia and Verma (2001) at the production level of 32 quintals dry leaves under rainfed conditions in Pali district appeared to be exaggerated since such yield levels are possible only under irrigated conditions. The henna crop with B/C ratio of 1.88 gives highest returns in comparison to other arable crops grown in the area during *kharif* season. Since the crop has a yield potential of as high as of 20 quintals leaves per ha (as found at CAZRI experimental farm, Pali) the returns could be higher with better management practices in this region.

Table 4. Returns from henna crop (ha^{-1})

Production (q/ha)	10.48
Price (Rs./q)	2532
Gross return (Rs.)	26529
Total cost (Rs.)	14079
Net return (Rs.)	12450
Return over variable cost (Rs.)	15482
Family labour income (Rs.)	16655
B/C ratio	1.88

Growth of Henna in Rajasthan

The area under henna plantation increased from 16408 ha (1991-92) to 30418 ha (2000-01) with an annual compound growth rate (ACGR) of 7.75 per cent while other arable crops either had low or negative growth rate in the same period (Khem Chand *et al.*, 2002). For example, the ACGR of Sorghum was 2.85 per cent, Pearl millet was (-) 2.52 per cent and Sesame was (-) 9.62 per cent. The favourable climate and increasing awareness among farmers regarding this crop played a great role in expansion of area under its cultivation in this part of arid Rajasthan. The occurrence of frequent drought also encouraged farmers to divert area in henna as farmers hardly get any income from arable crops during drought situation while henna gives at least some returns during this agriculturally harsh condition.

Though henna cultivation itself is also constrained by high labour cost, the profitability of henna and constraints in cultivation of arable crops are prime governing factors motivating the farmers to divert more area under henna cultivation. Introduction of some high level mechanical means, that could be improved implements or automatic machine for hoeing and weeding (serving soil working purpose also), harvesting, etc. of the henna can bring down the labour cost and that would be a huge step towards promotion of henna cultivation in the area.

References

Anonymous 2002. Agricultural Statistics of Rajasthan-2000-01. Directorate of Economics and Statistics, Yojana Bhawan, Jaipur, Rajasthan.

Kavia, Z.D. and Verma, S.K. 2001. Henna (*Lawsonia alba*): A profitable enterprise for rainfed agriculture in saline soils. In: *Symposium abstracts, Symposium on Impact of Human Activities on Thar Desert Environment*, Feb 15-17, 2001, Arid Zone Research Association of India, Jodhpur. pp. 82-83.

Khem Chand, B.L. Jangid and B.L. Gajja 2002. Economics of Henna in Semi-arid Rajasthan. *Annals of Arid Zone* 41(2): 175-181.

Singh, K.C. and Gupta, J.P. 1998. *Lawsonia alba* - cash crop for arid zone wastelands. *ICAR News* 4(3): 15-16.