Sunnhemp

(Crotalaria juncea, L)

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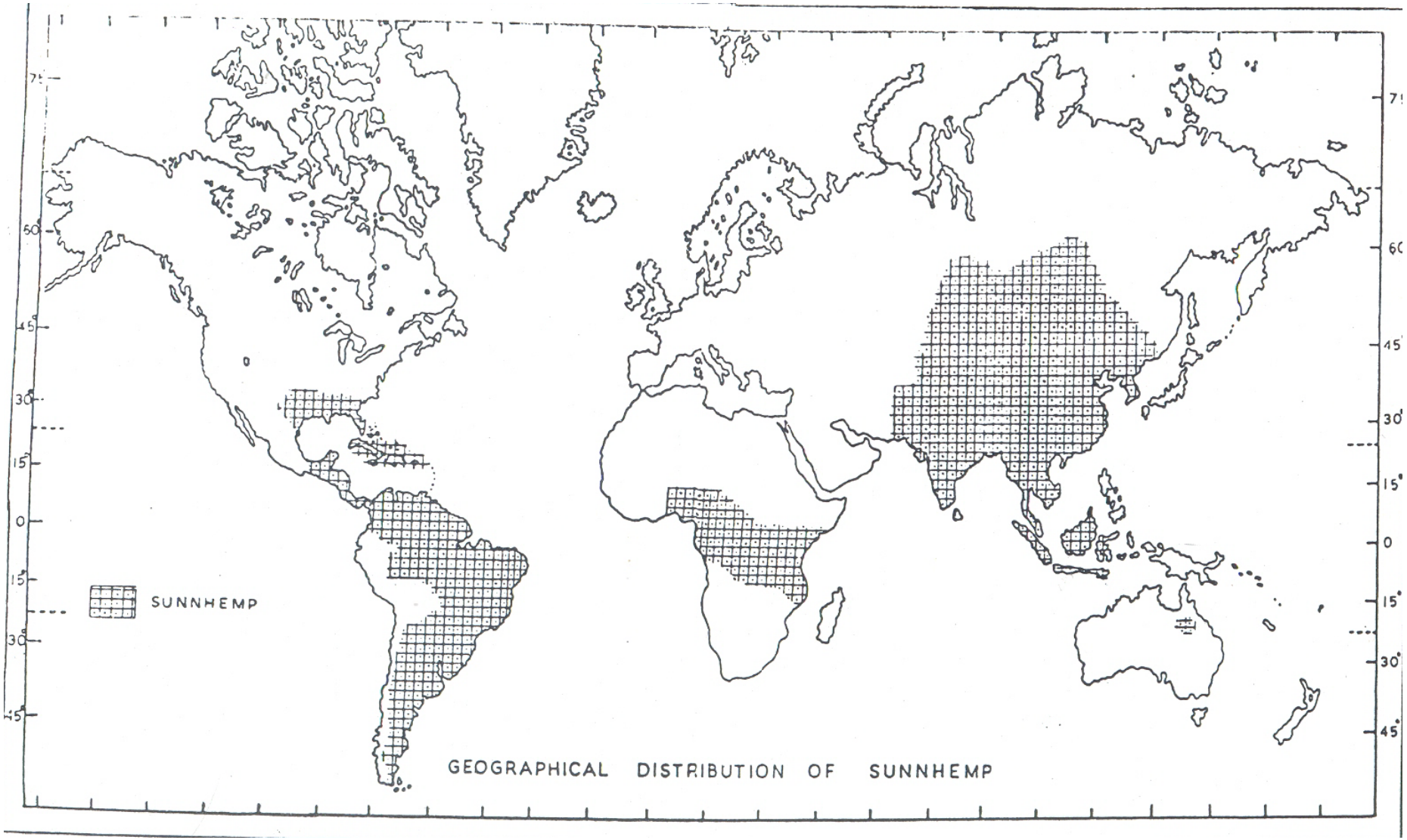
SUNNHEMP IN INDIA

The Phytogeography



GEOGRAPHICAL DISTRIBUTION OF SUNNHEMP

Sunnhemp *(Crotalaria aria juncea,* L), a plant of sub-order *Paplionaceae* of order *Leguminoseae* is an annual shrub cultivated as multipurpose legume especially for its fine fibre in many countries including India. The crop is grown also for legume or as a fodder. The genus name *"Crotalaria"* means 'rattle' and refers to the noise made by the seeds shaken in the mature pods. Species of this genus are wide spread throughout tropical, sub-tropical and to a lesser extent temperate countries. The sunnhemp crop is native to India. The crop is known in India by various names like 'Sonai' or 'San' (Hindi), 'Sanpat' (Bengali), 'Tag' (Marathi), 'Vakku' (Malayalam) 'Sanpat' (Oriya), 'Janumu' (Telegu), 'Saab' (Kannada).

EARLY HISTORY

It is one of the earliest (400 B.C.) of the distinctly named fibre of India, being mentioned in the early Sanskrit under the name of Sana (Royle, 1855). It is enjoined in the laws of Manu that the sacred threads used by 'Khatriyas' or Rajput (warrior class) should be made of 'Sana' (Kundu, 1964). The 'Ain-IAkbari' (1590) has clearly described two types of fibre plants one with flowers like cotton and the other with yellow flowers. The former can no doubt be *Hibiscus* and the later can only be *'Crotalaria'.*

The fibre from the Indian Sunnhemp was first introduced into Europe in 1791 and 1792 by the East India Company (Mukherji, 1953). During those early years, jute was considered as fibre plant of less importance. It was Roxburgh (1815) who proved that the quality of fibre of sunnhemp is excellent and not at all inferior to European Hemp. Later on Watt (1908) confirmed that sunnhemp was a far superior fibre than jute.

Sunnhemp as a fibre and green manure crop is cultivated in all states of India. It also serves as a good fodder crop in many parts of the country and is the largest producer of sunnhemp fibre followed by Bangladesh and Brazil. Of late, China is the highest yielder of sunnhemp fibre in the world.

AREA AND PRODUCTION

As stated earlier, sunnhemp is grown in almost all states of India either as a fibre crop, green manure or fodder crop. The states of Bihar, Madhya Pradesh, Maharastra, Rajasthan, Orissa and Uttar Pradesh grow this crop mainly for fibre. These states cover nearly 87 per cent of the total area under cultivation of sunnhemp crop. Among these states, Orissa alone produces 26 per cent of the total sunnhemp

produced in the country. Average productivity in the country is around 600 kg ha^{-1}. The most concentrated sunnhemp growing districts of U.P. are Varanasi and Jaunpur, Aurangabad and Jalana are the two main districts of Maharastra, which cultivate this crop in large scale. Besides, Ganjam District of Orissa also grows this crop. Above five districts accounts for 20 percent of the country's area and 23 per cent of production. The fibre yield in the Balasore and Sundargarh districts of Orissa and Chittaur districts of Rajasthan is the highest in the country followed by Ganjam and Kalahandi districts of Orissa.

Sunnhemp crop

Besides India, the crop is cultivated in many other countries like China, Korea (DPR), Pakistan, Bangladesh, Romania, Russia and CIS countries. These countries cover nearly 320 thousand hectare producing approximately 200 thousand metric tons of fibre. The six countries mentioned above cover nearly 92 percent of World's coverage with 83 percent of total production. India contributes 23 percent of production with 27 percent of world's area under cultivation.

GERMPLASM

Out of several well recognised types 'Madaripur' and 'Seraganj' are best known in Pakistan. The first one is considered best having creamy white fibres of good strength, relatively free from dirt. 'Somerset' is a good cultivar in South Africa. Similarly, KRC-1 in Brazil and 'Tropical sunn' in U. S. A. are good cultivars.

In India, 'T-6' is a day neutral. The variety 'K-12 yellow' which is the result of mass selection (Sircar, 1948) is a proven cultivar of 'Kharif-sunn' superior in yield to all other cultivars (ST-42, ST-55, ST-112, ST-95, M-19, M-35, Chindwara, Bellary, Jabalpur, Belgoan, BE-1 etc). It is a longer growing cultivar, resistant to stem break disease exhibits tolerance to disease, draught, and insect and can grow well on lateritic poor soil in slopes and with weeds.

A new selection of Sunnhemp (SS 11) has been found to have clear edge over K-12 yellow. The varieties K-12 (black), SJ-67-42 and Chindwara in terms of fibre yield at 90 days cropage have proved the best for the last five years at Sunnhemp Research Station, Pratapgarh (U.P). A total of 122 sunnhemp germplasms are being maintained at Sunnhemp Research Station, Pratapgarh. Germplasm (SUEX 015) from Russia (via NBPGR, New Delhi) is found day neutral and early flowering type (30-35 days irrespective of sowing time).

BOTANICAL DESCRIPTION

The sunnhemp is a herbaceous shrub, annual, 1-3 m. tall, vegetative parts covered with short downy hairs, tap root long, strong with many well developed lateral roots and numerously branched, lobbed nodules. The stem is approximately of 2 cm. in diameter, leaves are simple with minute pointed stipules, petiole short, about 5 cm long with pulverous, blades linear elliptical to oblong, entire 4-12 cm long, 0.5-3 cm broad and bright green in colour. Inflorescence is a terminal open raceme, 25 cm long with very small linear bracts. The flowers, are showy small with five hairy sepals, shortly united at base, the lobes are pointed with 3 lower sepals united at base. The petals are deep yellow, the standard erect is about 2.5 cm in diameter, rounded, sometimes streaked purple on dorsal surface, the wings are shorter and keel is twisted, stamens are 10, almost free at base, 5 with short filaments and long narrow anthers and 5 with long filaments and small rounded anthers; fruit-an inflated pod about 3cm long, 1cm wide groved along the upper surface, with a short pointed beak, light brown when ripe, several seeded softy hairs;

seeds numerous, small flattened, dark grey to black loosened in the pod at maturity. Seed weight is variable, ranging from 18000 30000 per kg depending upon variety.

The chromosome number of this cross - pollinated crop is sixteen. The treatment with indole butyric acid partially overcome self-incompatibility and tetraploids have been induced by treating young root tips with Colchicine.

ECOLOGY

Sunnhemp is the fastest growing species of the genus and is very effective in smothering out weeds. Almost any well drained soil is suitable for 'kharif' crop. Sunnhemp grown during rainy season is mainly utilized as a green manure crop. For fibre, it is grown on fairly light well drained soil (alluvium soil-old or new) having sandy loam or loamy textured soil that retains sufficient moisture. Soil moisture per cent of 30 helps in good and effective germination.

Sunnhemp is a short day crop, but vegetative growth is favoured by long days. It can tolerate an annual precipitation of 49-429 mm, annual mean temperature of 15-37.5° C and pH of 5-8.4. However, the near neutral pH range (6-7) where phosphate availability high is found good for the crop.

The sunnhemp growing areas of India range from latitude 17 - 30° N with relatively high humidity. in the Northern Provinces of India, sunnhemp is grown as 'kharif' crop whereas in South India it is raised as 'rabi' crop where winter is not pronounced.

The sunnhemp survives in both tropical and sub-tropical climate. In Brazil, the crop is grown in Amazon belt under almost equatorial region to latitude of 22.5° in the States of Sau Paulo under humidity and temperature having moderate to heavy rainfall.

PHOTOPERIODISM

The date of sowing has direct bearing on the vegetative growth and development of sunnhemp. The crop sown immediately after the break of the monsoon gives significantly higher yields than those obtained from crops sown later (Kundu, 1964). Sengupta and Talukdar (1954) found the planting if made during the month of April to September, flower between September 1 to October 14. The best growth is obtained from plants sown in April and May. As the vegetative growth period become progressively shorter with later plantings, the plant height becomes progressively shorter. The number of internodes are fewer and the stem diameter

also becomes smaller. The response to later plantings is typical of other fibre bearing species such as jute, mesta, roselle and urena.

Xylocopa spp. pollinating the crop.

POLLINATION

The lowest flowers of the inflorescence open first and remain open for 2 days. The flowers open between 2 and 3 am. The dehiscence of anthers is complete in between 12 noon to 1 pm in about one hour and a half. The stigma remains receptive on the day of the opening of flower. In the bud the stamens with the linear anthers are longest and dehisce with bud. The filaments of stamens with ovate anthers then elongate, pushing the liberated pollen to the orifice of the keel. The stigma lies at the orifice above the pollen mass. The wings and the keel are articulated by a ball and socket joint. Large bees such as *Xylocopa* spp. and *Vegactile* spp. alight on the wings and set ball and piston mechanism into operation. The ovate anthers dehisce at the top of the keel at the end of the first day or following

morning and the pollen from them is liberated with the help of the bees. Extensive cross-pollination occurs and self-pollination only takes place after the stigmatic surface is stimulated by the bee or mechanically (Purseglove, 1968). According to Kundu (1964), seed setting is practically nil when the flowers are kept inside muslin bags. Slight scratching of stigma with the help of a camel hair brush before pollination also helps in getting good seed set in this crop. A normal pod contains nearly 10 to 15 seeds. Thus sunnhemp may be considered as a highly cross-pollinated crop, and the flower must be tripped as in alfalfa to be fertilized.

Pod setting in Sunnhemp.

VARIETIES CULTIVATED

A good number of varieties of Sunnhemp have been developed and released in the country. However, the variety which has become most popular is K-12 (yellow). This is a selection made from an old variety K-12 (black) developed by Prof. T.S. Sabnis of Government Agricultural College, Kanpur (U.P). The variety K-12 (yellow) was developed by the Central Research Institute for Jute and Allied Fibres, Barrackpore. The variety was officially released in 1971. It has the potentiality of yielding 15 q of fibre per hectare. No variety after that has been able to yield better than this variety till now at national level.

Besides this variety, some other varieties have been developed for specific areas with very limited adaptability. Some of the important varieties are described below -

i) K-12 (black): This variety was developed by Prof. Sabnis of Kanpur during 1923-26 following mass selection from a local type. The seeds of this variety are black in colour, yield upto 10-12 q fibre per hectare in 100-120 days maturity. It possesses fibre of good quality. It also shows some resistance to wilt disease and shoot borer Recommended for U.P.

ii) K-12 (yellow): The variety is a selection from the old variety K-12 (black). The variety has been developed by the Central Research Institute for Jute and Allied Fibres, Barrackpore. The selection was made at Sunnhemp Research Station, Pratapgarh (U.P.) and was released in 1971 for general cultivation. The fibre yield potentiality of the variety is 15 q ha-1. It has shown some resistance to wilt disease. The variety has wider adaptability.

iii) M-18: The variety has been developed by the Madhya Pradesh Department of Agriculture. It is a early maturing type with high yield potential. It is resistant to draught, suitable for light soils with low rainfall areas of M.P.

iv) M-35: This is more or less similar to M-18. It shows some resistance to shoot borer.

v) BE - 1: The variety was evolved at Sabour (Bihar) through selection from the local material. This is a popular variety of Bihar and Orissa. Both yield and fibre qualities are good.

vi) Belgoan: The variety was developed by Madhya Pradesh Department of Agriculture. This is suitable for heavy soil and is grown in M.P.

vii) Chindwara: Developed from material collected from Chindwara (M.P). Suitable for M.P. and other states.

viii) Jabalpur: This is also a selection from a type collected from Jabalpur region of M.P. Cultivated in M.P. and U.P.

ix) Bellary: Developed through selection from a local type. It is a high yielder and most popular in Tamil Nadu.

x) D - IX: The variety has been selected from a local type collected from eastern part of Maharastra state. It shows resistance to wilt disease and is popular in Maharastra.

xi) T - 6: The variety has been developed by the Central Research Institute for Jute and Allied Fibres through selection from a local type of Midnapore district of West Bengal. Most popular in W.B. as green manure crop.

xii) ST - 95 : This is a selection from a type introduced from Taiwan. It has also showed slight resistance to wilt and shoot-borer.

xiii) ST-55: This variety is a selection from a local indigenous type. Gives high yield of 14 -15 q ha -1. It has shown moderate resistance to wilt diseases.

A new cultivar of sunnhemp (SS II) has been developed at Sunnhemp Research Station, Pratapgarh which is a better yielder as compared to K-12 (black and yellow), SJ- 67-42 and Chindwara at 90 days cropage. This is in pipeline and awaiting release soon.

CULTIVATION

The crop is cultivated in a wide range of climate in all parts of the country. It grows almost in every type of soil but cannot stand water logging. Growth period is favoured by the atmospheric temperature of 23-30^{o}C and rainfall of 400mm.

Land is required to be ploughed properly. Good ploughing and laddering is done to make a fine tilth which is most suitable for the germination of seeds. The moisture percentage of soil should not be below 30 per cent as the big size seeds require high moisture for good germination.

a) Sowing time: It is cultivated mostly as a 'kharif' crop and is sown with the commencement of South-West monsoon in the month of May and June and harvested in the month of October. Kundu (1964) writes about the above sowing time.

However, in Ratnagiri and Panchamahal districts of Maharastra, 24-Parganas and Maida of West Bengal and Purnea region of Bihar, sunnhemp is grown as 'rabi' crop where it is sown in October-November and harvested in February-March.

For green manure purpose, the crop can be grown in any month where it is ploughed down normally within 30-45 days of crop age.

Sunnhemp is sown as broadcast crop in 90% cases. Sowing in lines or rows are advocated. The sowing is done in line by dropping seeds behind the plough keeping rows at 2530 cm apart. Normally seeds are put nearly 2-3 cm deep in the soil. The plant to plant distance is kept at 5-7 cm preferably through thinning. The germination is epigeal and seed germinates rapidly in about 3 days time.

The growth of the plant is very much influenced by the date of the sowing and the nature of rainy season in the early part of crop growth. Generally, the crop sown immediately after monsoon gives always higher yield than the crop sown at a later date.

b) *Seed rate:* Seed-rate is dependant on the germinability and soil moisture content. In row-cropping, 25 kg seeds per hactare is considered sufficient if germinability is 80% or above. For broadcasting method, about 35 kg seeds per hactare is required. The seeds are casted once from north to south and next from west to east to effect uniform distribution. After casting the seeds the soil is raked and laddered to bring the seed 2-3cm below soil surface.

c) *Weeds:* In broadcast, heavy seed rate ensures upright erect stems which helps to smoother the weeds. It is valuable for controlling Kans grass *(Saccharum spontaneum,* L). The crop, however, cannot control nut-sedge. Generally, weeding is not done. Care should be taken in weeding out *Ipomoea* spp. whose seeds germinate, grow, flowers and fruits at the same time as that of sunnhemp.

ROTATIONS

Sunnhemp as a rotational crop has a major advantage and being a legume it has potential to meet its requirement of nitrogen by fixation of atmospheric nitrogen by bacteriods located in the nodules in the root and good for soil renovation. The crop is useful in rotation with potato, tobacco and other crops that are subjected to nematode infection. The crop is also rotated with sugarcane, rice, wheat and jute. It is also favoured as a cover crop in citrus, tea, cocoanut and rubber estates. It has proved as a special rotational crop with cotton in

U.S.A. and with Kenaf in Cuba. In Brazil, sunnhemp is rotated with wheat, sorghum, sugarcane and beans (Barros Salgado et ai, 1972). In dry production, yield increased on an average of 41 % over control in eight locations when bean crop was followed by sunnhemp. (Mascarenhas et ai, 1967).

In India, cropping schedules found suitable are: Sunnhemp-Wheat; Sunnhemp-Potato; Sunnhemp-Mustard; Sunnhemp-Paddy-Wheat; Sunnhemp:-Mustard-Wheat. Arilong the various rotation tried, the Sunnhemp - Wheat rotation was found to be best where the yield of wheat was found to increase by 10 -15 percent.

MANURES AND FERTILIZERS

The mineral nutrition of legume is directly related to the mineral nutrition of Rhizobium. The mineral nutrient status can affect Rhizobium at a number of different stages of nodulation.

pH : Legumes usually need neutral to slightly alkaline soil for nodulation. Root hair infection and deformation and consequently the formulation of nodules are inhibited by soil acidity of around pH 4.5.

Organics: Greater population of *Rhizobium leguminosarum* has been found in soils treated with farm yard manure than in control unamended soil. The humic and fulvic acid content of soil organic matter may have an ameliorating effect as both appreciably improve rhizobial growth. It is advisable to apply organic manure @ 3 to 5 tonnes per hactare at the time of land preparation. The organic matter serves carbon and energy source to rhizobia.

Inorganics: Like all leguminous crop, sunnhemp is also not supplied with any nitrogenous fertilizer. The role of legume in enriching the fertility of soil by controlling nitrogen through symbiotic nitrogen fixation by Rhizobium is well established. However, for the initial boosting up of the crop sunnhemp is also sometimes supplied with 5 to 10 kg nitrogen per hactare. At CRIJAF, it did not produce any significant change in the yield of fibre (Chaudhury & Sinha, 1978).

Phosphorus is considered to be the most important nutrient element for leguminous crop. Application of phosphatic fertilizer resulted in a large population of rhizobia occurring in cultivated soil than in virgin soil. Phosphate increases the amounts of nitrogen fixed by increasing overall plant growth. Phosphorus @20kg P 2°5 ha^{-1} is recommended for sunnhemp.

Potassium fertilizer was also applied @40 kg K20 per hactare as a safe dose. The response from the combination of P and K (P 2oK4o) produced the highest response and yield (10.6 q ha-1) of sunnhemp fibre at CRIJAF (Chaudhury & Sinha, 1978). A high rate of potassium uptake was observed all throughout the growth period. Potassium levels of soil have been shown to have a reflection on the occurrence of rhizobium.

Calcium has an important effect on the rhizobial population in the soil. It is essential for pod filling of leguminous plants. It is rendered in the presence of calcium and magnesium

as carbonate and hydroxides. Calcium neutralizes the acidity which chiefly increases the rhizobial growth and survival (Munns, 1977). The requirement for Mg is more than Ca (Vincent, 1962). The total need of the rhizobia for Ca and Mg ions (0.5 mM) has been found to be approximately 20 times the specific requirement in respect of calcium ion and 5 times for magnesium (Vincent, 1962). Ca concentration below 0.2 mM inhibits nodulation. Mg salts have been found to stimulate nodulation in legumes.

Micronutrients are essential for the growth and nutrition of leguminous crops. The low concentration of zinc and manganese are required for the rhizobial species. Molybdenum has been reported to have a salutary effect on the growth and nodulation of leguminous plants. A small amount of molybdeunm (50 g ha-1) added to the soil or as foliar spray, markedly improve growth and nitrogen fixation.

Molybdenum is required in small quantities for N2 fixation process in the symbiotic system. It is required mainly for nitrogenous synthesis which help reduction of N2 to NH3' In acid soil, molybdenum availability is affected although present in ample quantity. Liming of soil to increase the. pH can overcome the molybdenum deficiency.

The synthesis of vitamin B. has been recorded by the rhizobia and is the reason for their cobalt requirement. Cobalt does not exert effects on the rhizobial multiplication in the soil or in the rhizosphere. The primary effect of deficiency is the lowering of number of nodule initials and such nodules as develop have very much lowered concentration of bacteriods. The load bacteriods number appears to be associated with defective synthesis of vitamin B12 and consequent effect on bacterial multiplication. Bacteriods are the seats of N2 fixation. At CRIJAF, cobalt (50 g ha-1) individually and in combination with phosphorus (@ 20 kg P20S ha $^{-1}$) and molybdenum (@ 50 g ha-1) brought about significant performance in fibre yield.

Like molybdenum, iron is another essential element required for the healthy growth of symbiotic nitrogen fixing system whether they are utilizing elemental or combined nitrogen. Iron is necessary for the nitrogenous activity and leghaemoglobin production. Boron is also essential for nodulation which starts almost at two leaf stage of the seedlings.

HARVEST

Harvesting of the crop at proper time is very important for ensuring not only better yield but also better quality of fibre. The proper time of harvest, however, differs from place to place. The crop is still harvested at pod formation stage in central parts of the country like U.P. and M.P. In the southern parts of the country, the crop is harvested at the pre-flower or full blossom stage. In Bihar, harvesting at green pod stage is preferred. The case is entirely different in Maharastra and West Bengal where the harvesting is done very late at fully matured pod-stage. Kundu (1964) states that there is little difference in strength and fibre quality at flowering or when the seed pods are fully mature. Since some income can be obtained from the sale of seeds, he recommended harvesting at matured pod stage. Various

experiments conducted have shown that it is better to harvest the crop at 50% flowering or early pod-stage to compromise between yield and quality of fibre. In any case, the fibre crops get ready for harvest in 90-100 days (pod formation stage) or 120-150 days (50% flowering onwards). Flowering normally starts in September.

Harvesting is normally done manually with the help of sickles at the ground level. In U.P. and Bihar the tops of the plants (approximately 30 cm) are cut at harvesting for use as a fodder. The thick and thin plants of equal sizes are sorted out and tied in the bundles of 20-25 cm diameter. The bundles are kept in the field for 2-3 days for shedding of leaves. In some areas, the leaves are removed by hand and plants are sent for retting immediately.

Areas where sufficient water for retting is not available, the plants are kept in bundles till next monsoon when water is available for retting. In the Ratnagiri district of Maharastra, the plants are simply spread on the ground for 10-15 days. The retting takes place due to sufficient dew which is quite heavy during nights.

RETTING

Retting is the process in which the fibre in the bark is separated from the woody portion by the action of microorganisms present in the water. The process involves steeping and keeping the stems submerged in water for certain periods.

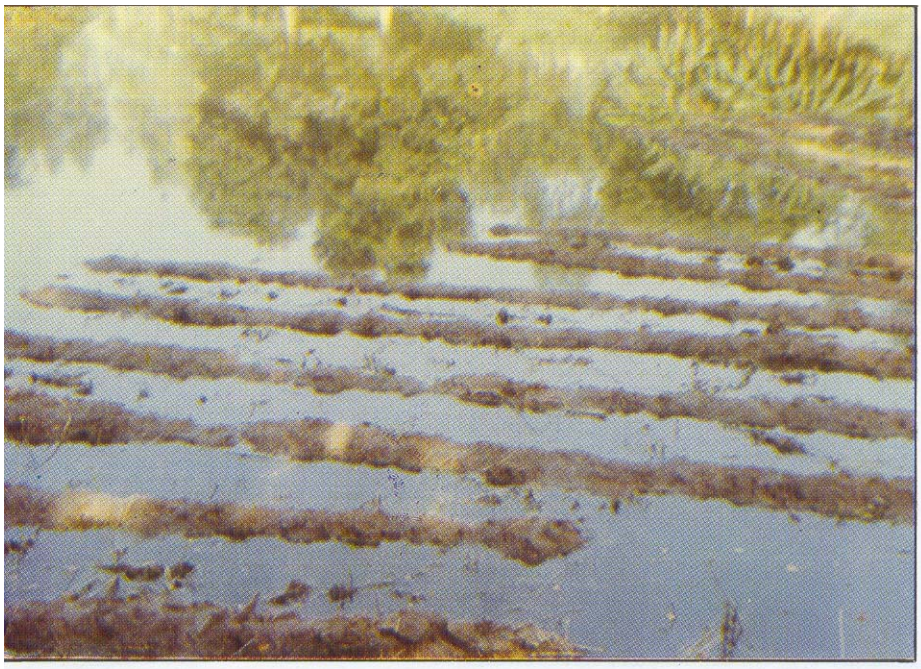
The number of days required for retting depends on water temperature, locality, time of year, weather conditions, depth and source of water, thickness of stalks and quantity of straw in relation to volume of water. Cement tanks are good for retting. But earth pits, drains, streams~ and back water pools of river are also used. If more than one ret is to be carried out in a pool, sufficient flow of water must be ensured to avoid fouling the water which discolours the fibre. Shaliow water of about 1 m to 1.5m deep can serve the purpose.

In the process of steeping, the bundles are arranged side by side preferably in single layer in the water. The bundles are weighted down with the help of some cement blocks to a depth of 10 to 15cm in the water. The weighted materials which release tannins (such as banana logs) should not be used. The retting period in India during September is 3 to 5 days. In cold water, retting takes about 7-9 days. If on testing of the retted stalks fibre is found loosening, it is considered ready for extraction. The softening of fibre takes place due to action of the enzyme released by the bacteria acting on the stem. The fibre is removed from the stem by hand. Precautions must be taken against under-retting or over-retting of fibre. In underrated condition, removal of fibres will be a difficult task as bark will adhere to the extracted fibre. While in over-retted condition, micro-organisms will break down the tissues surrounding the fibre and this will result in weakening of the fibre.

The methods of fibre extraction differ from place to place. The bark is partially removed by pulling a handful of the retted stalks between the thumb and the first finger. The stems are then stripped one by one. The person after breaking the lower end of the stalk gets free end of the fibre. He grasps this end of the stalk with his left hand and removes the

fibre in strips by running up the thumb and first finger of the right hand between it and the stalk. However, in some areas of U.P. and Bihar, the retted stalks are dried after they are removed from water. The fibre is then extracted from the dried stalks by breaking the stalks at different places and pulling it away from the wood portion. The fiber extracted in this way from dried stalks is of better quality than the fibre extracted from the wet stalks. One person can strip only the equivalent of 2.7-3.6 kg of dry fibre per day (Kirby, 1963).

Harvesting of Sunnhemp.



Steeping of Sunnhemp

Extraction of Sunnhemp fibre.

After extraction, the fibre is washed in water and dried in sun. The adequate washing leaves lot of gums which binds the finer component of fibre into coarse strands. The bundles of fibre are made by twisting the fibres in convenient sizes before sending it to market. In most areas of Andhra Pradesh, the fibre strands are not twisted but tied at the lower ends. In sunnhemp (K-12 yellow) with good retting, high grade white fibre yield of nearly 10-12q ha-1 can be obtained in farmers' fields.

MECHANICAL PROPERTIES OF SUNNHEMP FIBRE

Strength is one of the most important properties which largely determine the quality of yarn. This is usually expressed as tenacity, a ratio of breaking load of fibre (in g), to the fineness (in tex). Samples are taken either in the form of bundles of fibres to get bundle strength or in the form of single filament. Extensibility, fatigue property, torsional rigidity, fineness and density are other macroscopic properties of fibre.

Physical properties of sunnhemp fibres.

1. *Ultimate Cells*

a) Length (mm)	5-20
b) breadth (10-3mm)	12-35
c) Length/Breadth	450

2. *Filaments*

a) Gravimetric fineness (tex) b) Tenacity (g / tex)	5.5-17.0
b) Tenacity (g/tax)	30-40
c) Extension at break (%)	2.5-3.5
d) Modules of torsional rigidity (X 10^{10} dynes cm^{-2})	1-2
e) Flexural rigidity (dynes cm-2)	125-175
f) Transverse swelling in water (%)	18-20

3. *Bundles*

a) Tenacity (g/tex)	15-35
b) Density	
True (g/cc)	1.53
Apparent (g/cc)	1.34
c) Moisture regain (%)	
at 65% RH	10.5
& at 100% RH	28.5
4. Degree of crystallinity (X-ray, quantitative)	High
5. Herman's angle of orientation (X-ray in degrees)	9 – 10

Fineness: Fibres are entangled in mesh structure. Single filaments are obtained by combing- and splitting the mesh structure. The length and breadth ratio (LIB) of ultimate cell is a measure of fineness. The length and breadth ratio of sunnhemp (450) is much more than jute, mesta, roselle, sisal, coir, aloe, banana, manila hemp, bhindi, dhaincha and areca nut (75-140) indicating its finer nature. However, ramie, flax, true hemp and cotton (900 - 3500) are finer than sunnhemp on this count.

Tenacity: In terms of bundle tenacity, toss a jute and sunnhemp fall in the same group and have edge over white jute, mesta, roselle, bhindi, dhaincha, coir and aloe. Ramie, flax, true hemp, sisal and Manila hemp are stronger than sunnhemp fibre. This property of fibre is influenced mostly by retting conditions. Hence the above statements may not al
ways hold true. .

Density: The bulk density may be evaluated in terms of total volume of certain weight of the fibre, cut to a definite length, arranged in a particular way, and

put under a constant pressure. Any fibrous substance is obtained best by immerging it in some inert, non-swelling liquid. The liquid is allowed to permeate all air pores and the density thus obtained is the 'true' density of the fibre.

If the liquid used for immersion is a light mineral oil of low density, it enters the inter fibre spaces and envelops the fibre elements for a few minutes before penetratng into the micropores and lumen of the fibre. Density obtained before penetration occurs, has been termed as *'apparent'* density.

The co-efficient of correlation between yarn tenacity and apparent density is + 0.633 and between yarn tenacity and bulk density is + 0.559. Heavy bodied samples have a higher apparent or bulk density which in turn is associated with higher yarn tenacity.

These two values of sunnhemp fibre bundles are more in comparison to tossa and white jute, mesta, roselle, bhindi, dhaincha, sisal, manila hemp, coir, aloe, banana and areca nut but less than that of ramie, flax and true hemp.

Friction: Friction has an important role in yarn spinning. Both static and dynamic friction properties of all bast fibre crops have been studied. The co-efficient of friction of sunnhemp fibre are 0.50+0.02 r (parallel) and 0.40+0.004 r (perpendicular). These values are less than that of white jute, roselle, urena and ramie but more then tossa jute and flax.

CHEMICAL COMPOSITION OF SUNNHEMP FIBRE.

In order to assess the suitability of sunnhemp fibres for textiles or other end use, it is obligatory to get an assessment of chemical composition of the fibre.

Chemical composition of sunnhemp fibre.

1. *Major Constituents*

a) cellulose	78.3%
b) Pentosan	3.6%
c) Urinic anhydrite	1.7%
d) Acetyl content	1.5%
e) Lignin content	4.0%

2. *Minor Constituents*

a) Fat and wax	0.5%
b) Nitrogenous matter	1.4%
c) Ash	0.3%

3. *Monosaccharide constituents*

a) Glucose	80.3%
b) Xylose	5.2%
c) Mannose	11.7%
d) Galactose	2.1%
e) Arabinose	1.7%
f) Rhamnose	0.4%

Cellulose:

Apart from ramie, sunnhemp fibre has got highest amount of a - cellulose compared to all other bast and leaf fibres. The molecular weight is 1,32,840 (from chloride cellulose using 17.5% caustic soda) and 1,82,250 (Chloride cellulose using 9.3% caustic soda) as determined by viscometric method. The high a-cellulose content as well as degree of polymerisation or the chain length makes this fibre an ideal one for preparing specialty papers.

Hemi-cellulose:

The main hem i-cellulose fraction of sunnhemp is characterized as a 1, 4 linked glucomannon in which glucose and mannose are in the 1 :2.1 and joined by glucoside bonds. There is also a branch point connected to the main chain by 1,6 links. The degree of polymerisation of glucomannon is estimated as 49 and most of the non-reducing end group is comprised of glucose residue. A portion of glucose and mannose in the molecule are contiguous, but mostly they remain as alternate units.

PEST AND DISEASES

Sunnhemp is not affected by too many diseases and pests. A timely action to control diseases and pests help in getting a good crop. Important diseases and pests of Sunnhemp and their control measures are discussed below -

Diseases*:* The major disease is the wilt caused by *Fusarium udum Butt. f. sp. Crotalariae.* It attacks the young plants causing wilt and necrosis and in the older plants causing yellowing of the leaves which leads to eventual necrosis. It was stated that wilt is caused by continuous planting of sunnhemp on the same land and recommended crop rotation (Medina, 1959). The variety D-IX is resistant to wilt while K-12 yellow and some others show some degrees of resistance. Crop rotation, clean

cultivation and seed treatment with 0.15% Bavistin are the most effective and feasible remedy. However, well drained soil with good moisture retention capacity help escape infection. Spraying of Bordeaux mixture or 0.15% Bavistin on the first appearance of disease proved beneficial.

The second serious disease of sunnhemp is *anthracnose* or stem break (*Collectorichum curvatum - Briant and Martyn)* found in India and Southern Rhodesia (Mitra, 1934; Whiteside,1955; Kundu, 1964). Whiteside recommends the use of disease free seed, seed treatment with fungicide, early planting and rotations. Kundu recommends .seed treatment with fungicide, early planting and spraying the crop with Bordeaux mixture.

Other diseases like rust *(Uromyces decoratus)* and Sclerotenia rot are of sporadic occurrence and not difficult to control, K-12 yellow has proved to be largely resistant (Ghosh et ai, 1977). Many strains of sunnhemp often are attacked by *Benisia tabaci* transmitted virus which causes leaf mosaic, yellowing and crinkling of the leaves and weak stems that lodge easily resulting in low fibre yields. This is a serious disease but not of frequent recurrence. Powdery mildew *(Oiduim sp.)* attacks only older crops. The diseased plants may be uprooted and burnt.

Pests: The two major insect pests of sunnhemp in India are the top shoot borer *(Laspeyresia pseudonectis* Meyr) and sunnhemp moth *(Utethesia pulchella* L). Both cause tremendous damage to the crop each year despite the use of some semi-resistant varieties (Kundu, 1964; Dempsey, 1975).

The adult of the genus Utethesia is commonly known as bella or sunnhemp moth; however, this insect is injurious only in larval stage. It first attacks the leaves but prefers the pods. It is voracious feeder and one larvae can completely gut a large number of seed pods.

The top shoot borer has caused an 19.5% loss of plants in K-12 black and 15.41% in K-12 yellow, as recorded in Sunnhemp Research Station, Pratapgarh, U.P. The larvae of this species bore into the apical tips of the plant, causing branching and cessation of growth. There is a recommendation of the use of Diazinon applied as 4 to 5 sprays at 10 day intervals at a concentration of 0.04% beginning from the 20 days crop age. Alternatively, carbofuran 3 G @ 0.5 kg ha^{-1} once as soil application, followed by two sprays with 0.1 % Carbaryl 50 WP (i.e. 2g carbaryl in 1 litre water) may also be applied. Dimecron (0.06%) or Metasystox (0.075%) has been found effective when applied at 20 days of crop growth.

The caterpillars of the genus Argina do extensive damage to sunnhemp, feeding principally on the leaves. It may be effectively controlled by dusting with 5% BHC.

The sap sucker *(Ragmus importumitas)* can be controlled by dust consisting of 20% toxaphene and 40% sulpher plus an inert dilutant applied @ 10-15 kg ha^{-1} or by Dieldrin applied in the from of low gallonage spray @0.1 kg ha^{-1}. The flea beetle *(Longitarsus belgaumensis* Jaq) is highly susceptible to DDT. A 5% dust applied @ 10-15 kg ha^{-1} control this insect (Dempsey, 1975).

SEED PRODUCTION

Sunnhemp being highly cross-pollinated crop, selection of locations where sunnhemp is not grown traditionally is very important. The genetic purity of the cultivar can be maintained by eliminating the contamination of some local varieties. Statistics regarding seed requirement is lacking, since the information on massive quantity of seeds used for green manuring is not accounted for.

The seed yield from sunnhemp is highly variable, depending much upon variety, the time of planting and incidence of diseases and insect pests. The seed crop is raised in a late 'Kharif' season i.e., in the early August in the sunnhemp growing districts of Northern Provinces. But it is ideal to grow a seed crop in the rabi season in a zone where winter is not severe and the temperature do not fall below 10^0C (Ghosh et ai, 1977). The region selected for seed production should preferably have the following criteria:

(i) latitude below 24°N.

(ii) mild winter where temperature does not go below 10^0C.

(iii) should have good sunshine and

(iv) no rainfall during fruit setting.

In optimum condition, the seed yield may range between 18-20q ha^{-1}. The hundred seed weight ranges from 3.4-6.0 g depending on varieties.

The K-12 yellow and other varieties/strains of sunnhemp are short-day flowering types. The choice of season should be such that the vegetative phase is reduced to minimum while productive phase can be of longer duration. Therefore, best season is to grow sunnhemp during mid September to November.

In regions like M.P., U.P., Punjab, Rajasthan and Western Bihar where temperature goes below 10^0C, sowing time is to be selected sometime around August.

In West Bengal, three major co-habitative pollinating insects are found in the crop season around the year. The C.N.J.S.M. Farm, Bud Bud, Burdwan, West Bengal was specifically established by CRIJAF for production of Breeders' Seed. Other districts of West Bengal like Bankura, Purulia and Midnapore also satisfy the conditions for production of sunnhemp seed.

The pollinating insects belong to the *Hymenoptera,* the bee family:

1. *Xylocopa latipes Fabr*

The large sized bumble bee, a social insect of lower level of organisation than the honey bees. It is polytropic in nature. During a good flush of flowering in sunnhemp, the bee is found in the area and with the lowering of flowering, the bees go back to the polytrophic foraging, The bees need a warm humid climate. The bees while collecting the nectar and pollen from sunnhemp pollinate the crop.

2. *Xylocopa fensstroides Fabr.*

These bees are similar in every respect to bumble bee except it is slightly smaller as compared to bumble bee. This is a pollinator of other species of crotalaria as well.

Xylocopa spp. fertilizing the Sunnhemp crop.

3. *Mehachile lanata Fabr.*

These bees are poorly organised and found in greater frequencies in warmer months. The bees are very systemic in nature. They pollinate each flower of the plant before leaving for next plant.

Apis indica and *Apis flarea* are not effective trippers of sunnhemp flowers due to their small weight and body length, needed to make contact with stigma.

In seed production, two things should be taken care of. Firstly, there must be irrigation facility and secondly, a precaution against pod-borer, (the caterpillars of *Utethesia pulchella* Linn). Two or three sprays with Endrin (20 Ec) of about 0.01 concentration can control the infestation.

FIBRE AND QUALITY

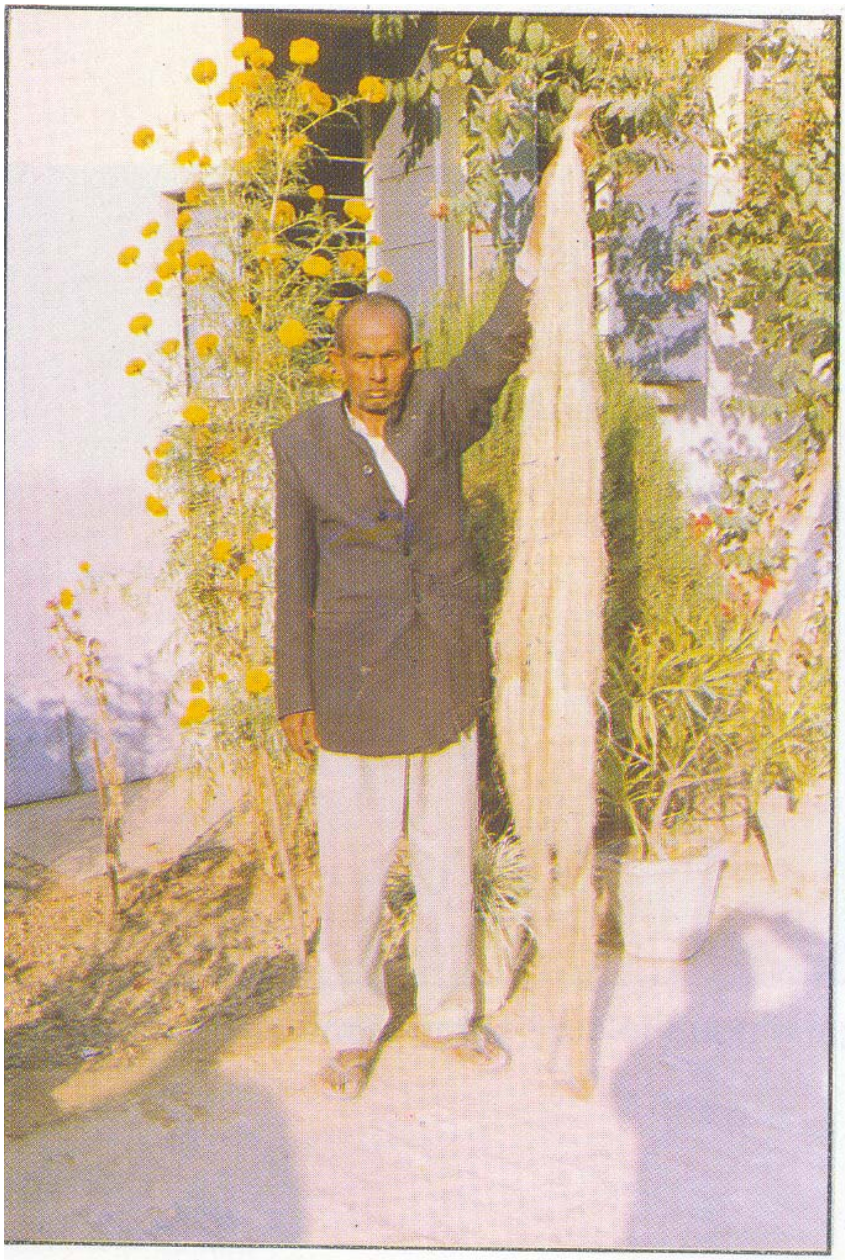
The appearance of yellowish white fluorescence in thin layer chromatography (chloroform: Ethanol: Di-ethylamine 50:40:10) help to identify the sunnhemp fibre even in admixture with jute, mesta and roselle (Mazumdar and Day, 1975). The fibre of sunnhemp is formed like other bast fibre crops in the form of separate bundles just outside the cortex. It has been found that bundles of fibre consists of 20 to 50 fibre cells which are very closely attached to each other.

The sunnhemp plant contains nearly 3 per cent fibre on total green weight basis and about 13 per cent on dry weight basis against nearly 5 per cent in jute on green weight basis. The ultimate fibre cells of sunnhemp are 3 to 5 mm in length with ends tapering abruptly. The fibre bundles originate as elements of the protoplasm of the primary vascular bundles. This is termed as 'primary fibre'. The 'secondary fibre' is developed by the cambium in connection with the formation of secondary phloem. The fibre in this crop is mostly primary fibres whereas in jut~ and mesta secondary fibre comprises of 90% of the total fibre production on the stem. The length of primary fibres varies from region to region in the stem. The largest fibres is generally found in the middle portion of the stem. The length of primary fibres varies from 3.91 to 4.38 mm and breadth from 26 to 40 11. The secondary fibre are much short with a length of 1.55 mm and breadth of 30 only.

The characters like length, strength, fineness, colour and uniformity constitute the quality parameters. Broadly, sunnhemp fibre is graded in three different grades viz. white, ganjam or green and dewghuddy. The quality of fibre varies in these three broad grades. The fibre of white type is 61-168 cm. in length, white or grey in colour with shinning lustre and fine texture. This type of fibre constitutes more than 60

percent of the total fibre production of the country. Fibre obtained from the ripening stage of harvest comes in the category of green or ganjam type. This fibre is stronger than white fibre and commands a much higher price. The green type represents 39 per cent of total production of the sunnhemp fibre in the market. The Dewghuddy type of fibre is produced in a very less quantity i.e. hardly one per cent. This third type of fibre is a very fine fibre, cream coloured and with very fine texture and about 81-82 cm long. This Dewghuddy fibre fetches 75% more money than average fibres in the market.

The strength of cordage fibre of sunnhemp is 185 kg as compared to 157 kg for cotton rope, 132 kg for hemp and 102 kg for coir.



Processed Sunnhemp fibre.

Dewghuddy-The finest grade fibre of Sunnhemp

GRADING OF FIBRE FOR MARKET

As mentioned earlier, the fibre of sunnhemp is classified into three major groups viz., white, Ganjam or green and Dewghuddy. However, for market purpose the fibre quality and grading is done on the basis of the time of harvest of the crop. Generally, the crop is harvested at pre-flowering, flowering and ripening stage. The character of the fibre under these harvesting stages is discussed below:

(1) ***Pre-flowering stage:*** If the crop is harvested at this stage, it produces the finest grade fibre of the Dewghuddy group. It produces fibre of Kantanbanji U.P. quality, Dohel quality, Calcutta quality and Bombay dressed type. The minimum length of fibre in this grade is 75-100 cm with a maximum refraction of 2.0-8.5 percent. The fibre is of fine texture and white in colour. This fibre produced is less than 2 per cent of the total production.

(2) ***Flowering stage:*** The crop is generally harvested in flowering stage in almost all the states. The fibre extracted from such plants falls in four subgrades i.e. Benaras, Bengal, Chapra and Gopalpur. Each sub-grade is further sub-divided in three different classes like Benaras-1, Benaras-2 and Benaras-3 and similarly in Chapra, Bengal and Gopalpur characters of each subgrade and classes are given below:

The finest sub-grade of Benaras (white) possess white or grey colour with high lustre and fine texture. Nearly 60 per cent fibre falls in this group. Another

subgrade is Benaras fine and has a fibre length of 100 cm with maximum refraction of 5 per cent. The fibre is white, clean and reasonably dry. Besides this, there are two more subagrades called Benaras-1 and Benaras2. Fibre of these two subgrades have maximum length of 90 cm and maximum refraction of 10 and 12.5 per cent respectively. The fibre is pale white to grayish white and has reasonably uniform strength with practically no Banwar.

Bengal grade fibre falls in three subgrades of Bengal-1, Bengal-2 and Bengal-3. The fibre of first two subgrades are more or less similar in nature. The minimum length of the fibre is 90 and 75 cm and maximum refraction of 2 and 2.5 per cent respectively. The fibre of these two sub-grades are creamy white in colour. The fibre of Bengal-3 possesses maximum refraction of 3.5 per cent and creamy to grayish white in colour. The fibre is free from tangling.

Chapra grade has four subgrades of Gopalpur white, Gopalpur brown, Gopalpur dark and Gopalpur shorts. All these subgrades have minimum fibre length of 90 cm with maximum refraction of 3.0, 4.0, 5.0 and 8.5 percent respectively. The fibre colour of Gopalpur is yellowish white and of Gopalpur brown is grayish to light brown. Gopalpur dark subgrade has dark colour fibre and Gopalpur shorts has yellowish white to light brown colour of fibre. The fibre of these subgrades are clear, dry and have uniform strength.

(3) *Ripening stage:* The fibre of this stage is classified into five types. They are Ganjam or green, Itarsi extra fine, Itarsi fine, Seoni fine and Jabalpur fine. The fibre of Ganjam or green type is of greenish colour and is stronger than white.

The *Itarsi extra fine* type has the minimum length of 100 cm with maximum refraction of 2 per cent. The colour of the fibre is creamy to pale greenish. The Itarsi fine type has minimum fibre length of 100 cm and maximum refraction of 3 per cent. The Seoni and Jabalpur fine have minimum fibre length of 100 cm and maximum refraction of 4 and 5 per cent respectively.

The *Jabalpur fine* type is pale greenish to light brown in colour and the fibre is clean and dry. The Jabalpur type also has another type called Jabalpur No.1 which is more or less like Jabalpur fine with same good length and refraction. However, the colour of the fibre is greenish brown to grey.

MARKETING

The fibre is sold generally by the cultivator to village dealer. The village dealers collect fibre from different villages, districts and take it to the nearby market. The fibre of different grades are collected in the market and taken to the fibre dealer or middle man who is normally stationed at the district level. Here the fibre is again sorted out and according to the grade determined. The fibre thereafter is baled into bundles called 'Kutcha' bales for the convenience of transport. The bales prepared at different centers are of different sizes and weights. The weight of bales may vary from 40-125 kg each. The fibres if found to be proper, can be straightway baled in 'Pucca' bales. The common size of pucca bales is 124 x 51 x 46 cm approximately.

The sunnhemp fibre is sometimes exported mainly to U.S.A., Great Britain, France, Italy, Belgium, Argentina, Greece and Russia. The export market has, however, now gone down badly due to availability of Italian and Russian hemp in sufficient quantity in the world market.

USAGES

There are varieties of purposes for which sunnhemp is now used. A short description of the multifarious usages of sunnhemp is given below.

Sunnhemp as *Green Manure*

The whole green plant is widely grown throughout the world as an excellent cover crop (green manure). Certain characteristics contribute to its usefulness as a green manure.

(i) Root nodulate freely and fix nitrogen-60 to 80 kg or more per hectare;

(ii) Plants are erect, fast growing and compete effectively with weeds and need no further care until ploughed down after 45 - 60 days;

(iii) Plants are generally drought resistant and high yielding;

(iv) The crop can be grown on infertile soil;

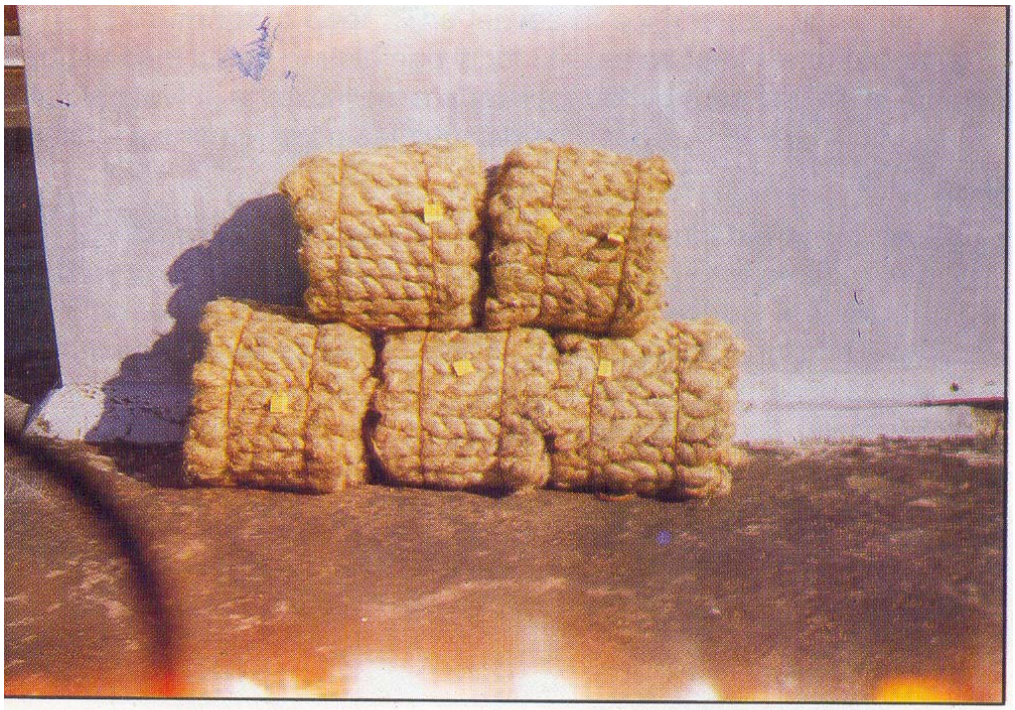
(v) It is useful for rotation with potato, tobacco, sugarcane, tea, coffee and other crops which are sub jected to damages by nematodes.

Sunnhemp as *Forage Crop*

The green plant is also used as forage crop to some extent but it will never be important because of (a) seeds and other parts of the plant contain poisonous substance, (b) coarse fibrous stalks are unpalatable and of questionable food value

and (c) early cuttings ensure good forage but contribute to low yields. In fibre producing states, plant tops are sometimes removed and fed to cattle.

As regards' toxicity, it varies from strains to strains and varieties in use and difference in plant maturity at harvest. High alkaloid concentration is the greatest feeding danger which lies in the seeds. Hence whole plant could be harvested prior to seed maturation and can be fed with less or no harm to livestock. Physiological changes due to abnormal conditions like draught may also have a bearing on the degree of toxicity.



Bundles of Sunnhemp fibre for transportation.

Sunnhemp Leaf: The leaves of sunnhemp contain 2530 per cent crude protein and if not utilized as fertilizer or forage would provide an excellent material for dehydrated leaf meal for livestock and poultry meal supplement.

Sunnhemp Seed: The seeds of sunnhemp are a secondary source of income. It contains 30-35 per cent proteins and can be used for making adhesive for plywood industries. Sunnhemp seed contains 12.6% oil with 4.6% linolenic acid, 46.8% linoleic acid and 28.3% oleic acid with by difference 20.3% saturated acids. Besides, the seeds are sometimes used medicinally. It is said to purify the blood. Seeds are used in impetigo, psoriasis, urinary crystalluria and as an emmenagogue.

A very mysterious substance - *'Trypsin inhibitor'* is present in the seed and alkaloid like - *'Retusamine - N-oxide'* is also present in *Gratalaria juncea.*

Sunnhemp seed contain:

Moisture	8.6%
Crude protein	34.6%
Fat	4.3%
Starch	41.1%
Fibre content	8.1%
Ash	3.3%
Oil	12.6%
Saturated fatty acids	20.3%
Linolenic acid	4.6%
Linoleic acid	46.8%
Oleic acid	28.3%

Adhesive from Sunnhemp Seed Protein.

Grotalaria juncea seeds have not so far been found in any commercial use. In 1975, D.Narayanamurty and P. N. Grover in ICAR Research Series No. D 5 have reported about the adhesive preparation from the proteins of sunnhemp seed. .

Types of seed protein present in different materials can be judged from the percentage of nitrogen extracted by various solvents. Sunnhemp seeds are characterized by a high percentage of water soluble proteins and all others by a high percentage of albumin and globulin.

Total Nitrogen in Solvent (%)

Materials	Water	Sodium Chloride	Alcohol	Alkali C
C. Juncea	75.63	21.70	3.15	90.0

In the case of Crotalaria juncea, the protein is also precipitated either by dialysis or electro dialysis. In addition, the borax or water extract of the seed is also tried for adhesive work.

Sunnhemp seed protein	100 parts
Borax or Tri-sodium phosphate	5 parts
Ammonia (27%)	4.5 parts
Formalin (4%)	22.5 parts
OR	
Furfural	27 parts

With this protein, borax extract of the seed proteins could be used as an adhesive after necessary addition of formalin.

Nutritive value of Sunnhemp drymatter as fodder

Crude protein	14.2%
Crude fibre	33.3%
Carbohydrate	38.6%
Ether extract	2.5%
Ash	8.0%
Calcium	0.73-2.08%
Phosphorus	0.19-0.51%

Sunnhemp STALK contains

Moisture	14.4%
Ether extract	1.1%
Albuminoid	14.39%
Carbohydrate	35.8%
Woody fibre	27.4 %
Soluble mineral	6.4%
Albuminoid ratio	3.4%
Food units	66.9%

Raw Sunnhemp plant contains

Ash	0.61%
Hygroscopic water	9.6%
Aqueous extract	2.8%
Fat and wax	0.55%
Cellulose	80.0%
Pectin bodies	6.4%

Sunnhemp for Paper Making

The whole dry stems of sunnhemp may provide a new economic crop for paper industries. USDA Research at the Northern Regional Research Laboratories, Peoria, Illinois showed that the whole stem possess good pulping characteristics with a high macerate yield pulp that appears suitable for a wide range of uses. As a consequence of the studies, the utilization of sunnhemp plant for paper making aroused much interest in USA and other countries. Sunrihemp, stems rated second

only to mesta as a raw materials for paper. A trial was carried out in Brazil, to find out the best varieties and cultural methods of sunnhemp crop for paper pulp making. Medina et al (1961) recommended the Use of 112 kg ha-1 seed in Brazil planted in rows 20 cm apart if stems are desired for paper pulp making. White and Haun (1965) in the United States recommended only 16.5-22.0 kg ha-1 of high quality seed planted in rows of 30-36 cm apart. For paper making purpose, the highest yield of dry stems occur late, but this does not affect the quality of paper. Thus it was recommended to harvest the crop at mature seed pod stage, which would be about 180 days after planting. When sunnhemp was decorticated in the green stage with a raspador decorticator in Brazil, the resulting crude dry bast fibre which was pulped for high grade specialty papers, contain impurities, including portion of epidermis, plant gums and woody stem. Nevertheless, these ribbons yielded a high percentage of easily bleached pulp.

Jain (1961) and Misra (1963) pulped the woody stems which gave a fair yield of short-fibred pulp with the individual fibres averaging about 0.7 mm in length.

This pulp is similar to that of bagasse and is suitable only for lower grade cheap paper. However, when the pulp was mixed with 20% bamboo pulp, the resulting blend made a paper possessing good qualities of strength, flex and tear.

Lai et al (1967) gave the excellent results obtained in Taiwan from new sunnhemp introduction as a source of raw material for high grade paper. Since Taiwan grows large acerage of sunnhemp each year as a cover crop for sugarcane, it is expected that this country will utilize this crop for dual purpose, green manure and for paper pulp. The lower grades of fibre, tow, old rope and crude decorticated fibre have long been used for the manufacture of high grade paper either alone or blended with flax pulp. The ultimate fibre of sunnhemp are long (L/B-450) and are highly suitable for such fine papers as bond, tissue paper (cigarette paper), condenser and Bible. Sunnhemp paper is used in the preparation of currency notes also.

Use* of *Sunnhemp retted fibre

Sunnhemp is grown primarily for cordage used for rope, string and fishing nets. Cordage made from sunnhemp is considerably stronger than that of jute but weaker than true hemp. It is also resistant to salt water. The tow from retted fibre is used for marine caulking.

By adopting flax spinning machinery for sunnhemp, It is possible to produce coarse fabrics for hose pipes, belting and canvas. In U.K and Belgium twines cords,

matting, sacking, tarpaulins, soles of shoes, sandals and marine cordage are produced.

The other products include rugs, carpets, webbing, table and bed linen (Wealth of India, pp 377-378).

Sunnhemp against Root-Knot Nematode and Weed

Sunnhemp has been reported to be effective in preventing a build-up of root-knot-nematodes when grown in rotation with Kenaf and many other crops, Good weather condition and heavy seedling rates enables to smoother the weeds. It is also valuable for controlling Kans grass *(Saccharum spontaneum).* This is proposed for a special rotational use with cotton in U.S.A. in reducing the incidence of cotton root-knot.

Minor usage of Sunnhemp

Some other minor uses are (i) woody stems after washing and extraction of fibres frequently used for fuel purpose and (ii) as an indicator plant to denote deficiencies of potassium and calcium in loose sandy and sandy loam cocoanut soils and marine oakum.

RESEARCH WORK ON SUNNHEMP

Research work in sunnhemp started in early nineties in this country. During the period of 1906-1910, Howard isolated a variety from local type and named it as 'Jabalpur'. He later identified a species of Crotalaria i.e., C. *tenuifolia.* Finlow (1960) studied the quality of fibre of this species and compared it with a famous local type of Bihar. He concluded that this variety is superior to that of Bihar type.

Prof. Sabnis (1931) later on stated that there is no difference between the Jabalpur type and *Crotalaria juncea.* Prof. Sabnis (1926) working on the improvement of sunnhemp for yield and quality, finally succeeded in evolving the variety K12 (black) which was high yielder with fine fibre (Report on Hemp. Harvesting, 1931).

Impressed by the work of Prof. Sabnis, the Indian Council of Agricultural Research sanctioned an ad-hoc scheme on the 'improvement of sunnhemp in 1936-37. The scheme was operated in four states i.e. at Central Province, Madras, Bihar and Bombay.

Sixty three cultivars were screened for preliminary examination for yield and quality. Out of these M-18 and M-35 were found to be early maturing types and high

yielder especially in areas with low rainfall. Dr. Uppal working with the Department of Agriculture, Bombay Presidency studied the biology of flower of sunnhemp. He found that majority of flower open in between 2 to 3 pm and dehiscence is over in between 12 noon and 1 p.m. in about one to one and a half hours time. The stigma are found most receptive the day of the opening of the flowers. Work conducted under the ICAR scheme revealed that the seed setting by self pollination is poor in this crop. The seed setting was found to increase when the flowers are pollinated by bees. The seed formation in the early sown crop was also found to be better than the late sown crop in the Bombay state.

Clouston (1908) worked on the extraction of fibre in Central Province. He found that the method of hand stripping of fibre with the help of finger nails is a costly practice since a person is not able to extract more than 6 to 8 kg of fibre in a day. He recommended extraction machine to make this operation cheaper and economical. Prof. Sabnis agreed to the recommendation. Mr. Churchill working on this aspect fabricated a machine for the purpose. Churchill used the flax scrutching machine for extraction of sunnhemp fibre. However, it was not found to be economical and efficient.

Dutta (1930) worked on the agronomy and retting problems of the crop. He recommended that 30-35 kg of seeds are required for covering one acre of land. He also observed that retting period varies from 4 to 10 days depending on the maturity of plants and temperature of water.

Under the ICAR scheme operated in four provinces, Department of Agriculture, Bihar developed a variety BE-1 (Nalanda Sanai) at Sabour. The variety became very popular in Bihar and yield was better than the local type.

The development of some good varieties lead to the conduction of full fledged yield trials to compare their yield and other characters. During 1940-42, the yield trials were conducted with five improved varieties i.e., Jabalpur, Chindwara, BE-1, Belgaon and K-12 Black in different locations spread under the states of Central Province, Maharastra, Bihar and U.P. The variety Belgoan was found superior in fibre yield.

Chindwara and Jabalpur were found to be at par with each other. Inspite of good yield the Belgoan variety could not become popular since the seed setting in this variety was very low. The seed setting was highest in K-12 Yellow.

Correlation co-efficient between plant height and basal diameter and fibre yield have been worked out. Basal diameter of stem has been found to be positively

correlated with fibre yield. The value of 'r' varied between 0.22 to 0.39 with different strains indicating the existence of low to moderate positive correlation. The correlation between the height and diameter of stem was found to be negative (Report on ICAR Sunnhemp Scheme of 1937-42).

During 1951-52 a varietals trial was conducted at Chinsurah to compare the yield of some more cultivars of sunnhemp like ST-104, ST-112, ST-114 developed by Central Research Institute for Jute and Allied Fibres, Barrackpore, the then JAR!. The varieties were not found to differ significantly as far as fibre yield is concerned.

Another varietals trial was conducted during (1954-55) to compare the yield of K-12 with other cultivars. The variety K-12 out yielded others.

Several interspecific crosses were attempted using different species like *Gratalaria juncea, Gratalaria retusa* and *Gratalaria medicaginia* to transfer some desirable characters like pod setting and resistance to disease and pests. However, in none of the cases seed setting was observed.

Experiments conducted on the seed rate have demonstrated that a seed rate of 60-80 kg ha -1 is good for raising an economical crop. The crop grown with higher seed rate produced fibre as compared to the crop grown with less seed rate. .

The effects of different dates of sowing was found to be highly significant with the fibre yield. The crop sown early gave higher fibre yield. The plants obtained from the crop sown late were found to be weak and short in height. The work conducted on the spacing has indicated that sowing of sunnhemp in 20 cm. spacing from row to row is better than the 30 cm row distance. The 4-5 cm plant to plant distance in a row has been found good for higher yields.

Sunnhemp has also been tried in different crop rotations. Among the various rotations tried, the sunnhemp-wheat rotation was found to be the best where yield of wheat increased by 10 to 15 percent.

Sunnhemp is sometimes supplied with 5 to 10 kg N ha^{-1} for initial boosting up of the crop. However, Chaudhury and Sinha in their study of growth and nutrient removal pattern of sunnhemp during 1976-78, observed that both 5 kg or 10 kg N ha^{-1} did not produce any significant change in yield of fibre. They also observed a higher uptake of phosphorus; But response from the combination of P and K (P_20_5@ 20 kg ha^{-1} and K20 @ 40 kg ha^{-1}) was prominent. The highest yield of 12.55 q ha^{-1} was observed at the above combination of P and K. A comparatively high rate of K20 uptake was maintained all throughout the growth period (JARI, Annual Report, 1976-78).

Chaudhury and Ray (1994) in another experiment studied the relative efficacy of seven methods of phosphorus application on dry matter yield, fertilizer phosphorus uptake and its utilization by Sunnhemp (K-12 yellow) under field condition using ^{32}P tagged single super phosphate. They observed that the fertilizer was least utilized by the traditional method of application Le., broadcasting, whereas placement below the seed was significantly superior to all other methods in relation to dry matter yield, total and fertilizer 'P' uptake by sunnhemp. The per cent utilization (5.1%) of fertilizer P added and percent Pdff (38%) followed the similar pattern as that of dry matter yield. The result of the present investigation have thus indicated that there was faster absorption of fertilizer 'P' from placement below the seed and could be applied for better utilization of phosphatic fertilizer and getting higher crop yield.

Both molybdenum and phosphorus have been reported to have a salutary effect on the growth and nodulation of leguminous plants. Cobalt is reported to be required for the metabolism of rhizobial cells though cobalt do not nodulate significantly. Thus to assess the influence of phosphorus, molybdenum and cobalt both in connection with the fibre yield and nitrogen content in sunnhemp, Chaudhury et ai, (1993) conducted an experiment at Sunnhemp Research Station, Pratapgarh (U.P.). They observed that the crop responded to the applied phosphorus, molybdenum and cobalt. Individually and in combination, each of the nutrients brought about significant improvement in fibre yield. Statistical analysis of data for fibre yield revealed that all the treatments and their combination were significant. Treatment P (20 kg ha^{-1}) Mo (50 g ha^{-1}) and Co (50 g ha-1) produced 12 q fibre per hectare (CRIJAF, Annual Report, 1995-96).

Singh et ai, (1991) in their study with PEG (PEG 6000) induced short term water stress effect on nitrogen assimilating engymes of sunnhemp root nodules suggested that under mild to moderate water stress for brief period, $N0_3$ reduction in sunnhemp nodule bacteroid is enhanced.

Research on the control of various disease and pests have been conducted during last four decades. Sunnhemp, a leguminous crop, attracts, quite a good number of pathogens like fungal, bacterial, viral, mollicute like organism (MLO'S), nematodes as well as paragistic phenarogenes. Some of this like wilt mottling virus, anthracnose and MLO'S occupy fairly high place specially at the Sunnhemp Research Station, Pratapgarh (U.P.).Besides, the chemical control measures, recommendation of some organic methods have also been used in this direction.

Neem cake @ 50 kg ha-1 has been found to be quite effective in controlling wilt disease. Similarly, the sunnhemp-bajra sown in alternate rows has been found effective in keeping the wilt disease in control. The wilt disease can also be kept in control if less quantity of inorganic fertilizers is applied. Higher atmospheric temperature and higher relative humidity are the two environmental factors which induce the incidence of wilt disease. The pathologist of Sunnhemp Research Station, Pratapgarh (U.P.) have isolated the following pathogens in the crop.

(A) PATHOGENS

(a) *Pathogens from leaf*

(i) Alternaria crotaricola
(ii) Cercospora cotigensic
(iii) Choaniphora curcurbitarum
(iv) Helminthosporium crotalariae
(v) Leveillula tau rica
(vi) Pellicularia spp.
(vii) Corrynespora cascicola
(viii) Curbularia spp.

(b) *Pathogen from stem*

(i) Gorticum soline
(ii) Colletotrichum curvatum

(c) *Pathogen from root*

(i) Colletotrichum curvatum
(ii) Drechslera spp.
(iii) Fusarium udum
(iv) Macrophomina phaseolina
(v) Mucor spp.
(vi) Pythium spp.
(vii) Rhyzoctina solani
(viii) Tricoderma

PESTS

(i) Lesperyresia tricentra
(ii) Uthathesia purchella
(iii) Nupserha bicolour

(iv) Cyaneolyte coerules

(v) Nezera spp.

At Sunnhemp Research Station, Pratapgarh (U.P) percentage incidence of sunnhemp wilt was observed ranging from 6-9 per cent in roving and 4-5 per cent in fixed survey. At Pratapgarh, it was also recorded that top-shoot borer causes an 19.5 per cent loss of plants in K-12 black and 15.41 per cent in K-12 yellow. Bandopadhyay et al (1982) on screening forty one germplasms against Fusarium Wilt disease found fifteen of them are moderately resistant and twenty six are moderately susceptible including K-12 Yellow. Bandopadhyay and Misra (1985) studying resistant in sunnhemp variety against infection of three plant parasitic nematodes observed that the variety K-12 yellow was resistant to *Meloidogyne incognita, Helicotylenchus digonicus* and *Hoplolaimus indicus* species of nematodes and have deterring effect on them.

In vitro studies on Sunnhemp

Pollen cultures were subjected to CO2 and 1 litre of (1-14 c) acetate per ml. of culture medium and lipids subsequently extracted and analysed. CO2 at 1 % increased the incorporation of radioactive acetate into total and polar lipids. Among non-polar lipids it promoted acetate incorporation in sterols only, but reduced incorporation in free fatty acids, triglycerides and sterol esters (Mallick et ai, 1989). This study was aimed to find the role of CO2 and organic acids in lipid biosynthesis during pollen growth in sunnhemp.

In another significant study, cell wall formation was initiated after plating isolated protoplasts from cotyledons of six day old seedling on modified Gamborg 85 medium. Divisions occurred and after 3-4 weeks colonies were transferred to fresh medium until they formed small calluses. After transferring to a differentiating medium, somatic embryogenesis was observed. Plantlets were regenerated from shoot bud from the callus (Rao et ai, 1985). In bast fibre crops, this is the only success of its kind and protolast engineering in sunnhemp is now a distinct possibility in near future.

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