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RESEARCH ARTICLE

LINSEED: A VALUABLE CROP PLANT

Janakinath Dash[1], Bhima Sen Naik[2] and Uma Ballav Mohapatra[3].

1. Nayagarh Autonomous College, Nayagarh-752 069, Odisha, India.
2. Orissa University of Agriculture and Technology- Chiplima Campus, Regional Research and Technology Transfer Station, Chiplima, Sambalpur-768 025, Odisha, India.
3. Government of Odisha - Science and Technology Department, Bhubaneswar-751 001, Odisha, India.

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Abstract

This article reviews the different aspects of economic botany of linseed /flax (*Linum usitatissimum* L.), namely, history and origin, morphology, area of cultivation, production and productivity, economic importance and cultural methods.

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Introduction

Linseed or flax (*Linum usitatissimum* L., 2n= 30, X = 15) belongs to the order Malpighiales, the family Linaceae, and the tribe Lineae. It is the second most important *rabi* oilseed crop and stands next to rapeseed-mustard in area of cultivation and seed production in India. The genus *Linum* is composed of approximately 230 species but cultivated linseed / flax is the only species of economic importance in the genus (Rowland *et al*., 1995; Tadesse *et al*., 2010) and is one of the oldest plants cultivated for fibre and oil. Linseed is popularly known as *Atasi*, *Pesi*, *Phesi* or *Tisi* in Odia. Although linseed plants have several utilities, it is cultivated commercially for its seed, which is processed into oil and after extraction of oil, a high protein stock feed is left (Sankari, 2000; Kurt and Bozkurt, 2006). Linseed oil has been used for centuries as a drying oil whose oil content varies from 33-45% (Gill, 1987). About 20% of the total linseed oil produced in India is used by farmers and rest about 80% goes to industries for the manufacture of paints, varnish, oilcloth, linoleum and printing ink etc. Fibres obtained from the stem are known for their length and strength and are two to three times as strong as those of cotton (Taylor, 2012). The fibre is lustrous and blends very well with wool, silk and cotton etc. Linseed has an important position in Indian economy due to its wide industrial utility. But the national average productivity of linseed seed is quite low as compared to other countries. In India, linseed is grown mostly under rainfed (63%), *utera* (25%), irrigated (17%) and in input starved conditions in major linseed producing states i.e. Madhya Pradesh, Chhattisgarh, Maharashtra, Jharkhand, Uttar Pradesh and Odisha (Srivastava, 2009).

Due to the availability of other cheaper petroleum products with equally good or some times better drying properties, the widespread use of linseed oil is restricted during recent times in the paints and varnish industries. However, linseed oil continues to be the base stock in medicinal, chemical, pharmaceutical and cosmetic industries as they have renewable, biodegradable properties and are non-allergic in nature along with enriched phytochemical contents.

Corresponding Author: Bhima Sen Naik
Address: Regional Research and Technology Transfer Station, Chiplima, Sambalpur, Odisha

In order to make linseed crop more remunerative and to generate employment, product diversification for medicinal and other industrial purposes of linseed needs to be improved by concerted research efforts. One of the major lines of researches is crop improvement programme through recombination breeding using elite germplasm for development of double purpose (oil and fibre) crops having high yield and stress resistance (both biotic and abiotic) qualities.

History and origin

The use of flax for the production of lilen dates back to 3000 B.C. as evidenced from the pictures on tombs and temple walls at Thebes of flowering flax plants. The use of flax fibre in the manufacturing of cloth in northern Europe dates back to Neolithic times (New Stone Age).The origin of flax (*Linum usitatissimum* L.), which is one of the oldest of cultivated plants is uncertain. However, it is generally accepted that linseed has originated from "Fertile Crescent"- an area east to Mediterranean Sea towards India (Zeven and Zhukovsky, 1975; Anonymous, 2010) and was probably first domesticated there. The generic name "*Linum*" comes from Celtic word *lin* means thread and the species name "*usitatissimum*" given by Carl Linnaeus, means very useful. So it directly refers to its multiple applications and their importance in ancient times.

Linseed is supposed to have originated in the four centres of origin, *viz.* Central Asiatic Centre, Near Eastern Centre, Mediterranean Centre and Abyssinian Centre. It spread northward to Europe and other parts of Asia and southward to India. But the botanical origin of linseed has not yet been determined with certainty. However, two theories such as polyphyletic origin and origin from the wild species of *Linum angustifolium* Huds. (2n=30) have been postulated (Gill, 1987).

Theory of polyphyletic origin regarding the probable progenitor of *Linum usitatissimum* L. is based on the postulation on the varying etymology of the names (*lin, llion, linu, linon, lien, lan, linseed* etc.), which existed in the Europian language and the antiquity of its cultivation in Egypt, Europe and the north India. According to this theory, the origin of the Indo-Gangetic types of cultivated flax (tall plants, small seeded and low oil content) originated through natural crossing of *Linum usitatissimum* with *Linum strictum* and the Peninsular types (shorter plants, bold seeded and more oil content) were derived through natural crossing of *Linum usitatissimum* with *Linum perene* or *Linum mysorense*. However, experimental evidences to support this hypothesis are still lacking, as it seems to have been based on observation rather than experimentation.

The view of origin of *Linum usitatissimum* L. from a single wild spices *Linum angustifolium* Huds. is from Mediterranean region, which might be the probable primary centre of origin of flax. It seems apparent that the species, which might have been cultivated by the lake-dwellers of Switzerland and Italy, was *Linum angustifolium* Huds. This theory is based on the archaeological remains of early civilization and enough experimental evidences. Both species are annual and grow in winter and have long slender stem with profusely branching system. They have small deep blue flowers and dehiscent capsules. The chromosome number in both the species is same (2x=30). However, available evidences indicate that *Linum bienne* Mill. a small seeded flax, might have contributed some germplasm to be the probable progenitor of *Linum usitatissimum* L. The species might have originated from Kurdistan and Iran. However, experiment by Muravenko *et al.* (2003) showed that three species *viz. Linum usitatissimum* L., Linum *bienne* Mill. and *Linum angustifolium* Huds. were assumed to have originated from a common ancestor, *Linum angustifolium* Huds. being closest to it.

Morphology

Linseed (*Linum usitatissimum* L.) is an erect annual herbaceous plant 30-120 cm, in height with slender glabrous, grayish green stem. The linseed types are grown for extraction of oil from the seeds. The flax types are grown for fibre extraction from the stems. The flax types are relatively taller (80-120 cm) in height with straight culms, less number of secondary branches towards the top of the stem (Gill, 1987). These plants generally produce fewer capsules and smaller seeds. The former (linseed) type is 60-80 cm in height and the plant has a short tap toot system with fibrous branches. The shoot is profusely branched and bushy in character (Plate 1). Leaves are without stipules, 20-40 mm long and 3 mm broad, simple, narrow, alternate, lanceolate, acute or acuminate with a smooth upper surface and grayish green in colour. Flowers are showy, variously shaped (Plate 2), regular, hermaphrodite, pentamerous, hypogynous and borne in loose terminal raceme or open cyme with blue, white or pink colour. The calyx consists of five ovate acuminate persistent sepals. The corolla consists of five free petals, imbricate or twisted in the bud, fugacious, often clawed, bluish or white, deciduous which fall before noon. The androecium has ten stamens present in two whorls. But the outer whorl consists of five stamens being reduced to staminodes. The inner five fertile stamens are widened to form a fused ring which surrounds the base of the gynoecium (Plate 3). The petals are narrow at their bases and insert into this ring. Nectar secreting glands are present at the widened bases of the stamens. In most of the flowers of *Linum usitatissimum* L., the anthers encircle and reach over top of the stigma, but in some varieties, the stigma extends beyond the anthers slightly. The anthers are two celled, introrse and dehisce longitudinally. The superior gynoecium consists of five united carpels. The ovary is ovoid and ten celled due to the presence of false septum in each carpel and producing up to two ovules in each carpel. Ovary has axile placentation and ovules are pendulous and anatropous with five styles, which are filiform, free or united below and twisted together forming slightly club-shaped stigmatic surface. Fruit is small round smooth globular capsule of 5-9 mm diameter. *Linum usitatissimum* L. is the only species with non-dehiscent or semi-dehiscent capsules for modern cultivation of the family Linaceae (Getinet and Nigussie, 1997). It contains up to 10 smooth, glossy an apple pip shaped, light brown colour seeds which is 4-7 mm long. In most of the varieties, the capsule is of indehiscent type. Linseed is predominantly self pollinating. Cross pollination can occur at a very low level (less than 2%)by insects (Tadesse *et al*., 2010).Wind pollination is not seen because the pollens are relatively heavy and sticky (Anonymous, 2010).

Area of cultivation, production and productivity

Linseed is being cultivated in Egypt, Europe and India since pre-historic times. The important linseed growing countries are India, Russia, Canada, Argentina, and the U.S.A. From the 21.12 lakh hectares global area, 41.62% i.e. 8.79 lakh ha. belongs to the Asian region with 5.35 lakh tonnes contribution to the total world production (21.23lakh tonnes). Productivity of this region (608 kg/ha) is approximately 60% of the world productivity of 1006 kg/ha (Anonymous, 2011a). India is the second largest (21.21%) linseed growing country in the world in terms of area of cultivation after Canada. Production wise, India ranks 4th (8.20%) in the world after Canada (40.51%), China (18.68%) and the USA (10.89%) (Srivastava, 2009). But as per Food and Agricultural Organization Statistical data (FAO-STAT, 2007), India ranks 3rd (9%) in the world's top 20 linseed producing countries. However, in terms of productivity, India (449 kg/ha) is far below than Canada (1492 kg/ha), USA (1484 kg/ha), Egypt (1469 kg/ha), Russia (1272 kg/ha) and China (944 kg/ha). Although, the area of cultivation of linseed is decreasing, the productivity is increasing not only in India (+17%), but also all over the world (+18%).

Now, linseed is under cultivation in as many as 13 states of India, *viz*., Madhya Pradesh, Maharashtra, Chhattisgarh, Uttar Pradesh, Jharkhand, Bihar, Odisha, Karnataka, Nagaland, Assam, West Bengal, Himachal Pradesh, and Rajasthan. At present, linseed is cultivated in about 3.420 lakh ha with the contribution of 1.537 lakh tonnes to the annual oilseed production of our country and the yield being 449 kg/ ha is far below the world production of 21.23 lakh tonnes from 21.12 lakh ha with productivity of 1006 kg/ ha (Anonymous, 2011a). However, there is significant increase in the productivity of the states like Rajasthan (2006 kg/ha), Bihar (846 kg/ha), Nagaland (689 kg/ha) and Assam (517 kg/ha) is at a par with Asia (608 kg/ha) and the world (1006 kg/ha).

Economic Importance

Linum usitatissimum L. occupies an important position in world market because of its multiple trade use. It is a valuable crop and every part of the plant has specific economic importance.

Uses of flax fibre

Flax fibre is one of the most natural and eco-friendly fibres among all the textile fibres. The characteristic features of flax fibres are their strength, fineness and durability. They are lustrous, stronger, less stretchy, more durable and more resistant to environmental fluctuation than cotton and jute. This fibre blends very well with wool, silk, cotton etc. Bundles of fibres look like blonde hair. The threads are very strong and so are used for shoe making, manufacture of fishing lines and nets etc. The fibre is extensively used in the manufacture of canvas, twine, carpets, blankets and mats. Rough and coarser grade fibres are used in the manufacture of strong ropes, shipping cord, twines and cordage, which are very indispensable for aeronautical and defense purposes. Flax fibre textiles which are called 'lilen' or 'linso-fabrics',in which best grades of flax fibres are used for manufacturing suiting, shirting, bedsheets, cloth laces, damasks, curtains etc. Flax-jute (Linju) and Flax-cotton (Linco) blended fabrics show better quality than cent-percent jute or cotton fabrics (Pandey and Dayal, 2003).

Pulp sweeteners

After extraction of fibre from stalk, the woody core of the stem and short fibres are used as raw pulp for making high grade paper. To increase the quality of the paper more than 20% strong virgin wood fibre must be added to the pulp. This extra strong fibre which is to be added to the pulp is called as "pulp sweeteners". As flax fibres are stronger and longer than any other virgin wood fibre, a small quantity of flax fibre can be used in place of virgin wood fibres. This pulp can be utilized for the manufacture of paper used for currency notes, air mail, parchment paper, good writing paper, cigarette paper and straw boards of all grades of economic value.

Geotextiles (Insulation)

Coarse and fine flax fibres are blended and processed to produce insulation batts (fibre wadded into sheets) having similar insulation properties to fibre glass batts in order to insulate walls and ceilings (Jacobsz and Vander Merwe, 2012).

Plastic composites

As flax fibres are cheaper and lighter in weight, these can be used in place of fibre glass in the manufacture of plastic composite applications (car dashboards, fencing materials, septic tanks etc.). Flax fibre is better known as plastic crop (Vittal *et al*., 2005), due to their importance in the use of paper and plastic in an eco-friendly condition.

Wax

Commercial wax is extracted from the cortical tissues by different organic solvents. This wax is used in shoe polishes (Gill, 1987).

Commercial industrial grade oil

Linseed oil is a versatile "drying oil" as it undergoes polymerization due to the presence of di- and tri-unsaturated fatty acids. So it is converted into a solid form when exposed to oxygen in air. The polymer forming properties facilitate linseed oil to use by its own or blended with other oils, solvents and resins etc. Raw linseed oil dries in a slow rate. It has tendency of yellowing with poor colour retention. In order to improve the drying and colour retention properties of linseed oil, some processes have been developed by heat modification (heating raw linseed oil at different high temperature range). Linseed oil is also blending or combining with dryers (compounds like linoleates or resinates of lead, manganese, cobalt, zinc etc) or with other compounds/chemicals to meet the demand for special application in dyeing industry. These oils are called modified oils and named as boiled oils (raw linseed oil heated at 90^0C-150^0C with dryers), blown oil (blowing air through raw linseed oil at 130^oc), stand oil (alkali refined), enamel oil (mixing of linseed oil with tung oil), sulphurized oil (linseed oil treatment with sulphur chloride), styrenated oil (reacting with styrene), esskol and solinox oil (hydrogen treated oil) and polymerized oil (treatment with chlorinated hydrocarbon with aluminium trichloride, boron trifluoride, silcon tetrachloride or titanic chloride). These oils have high industrial values as these types of oils are used in the manufacture of paints, varnish, waterproof materials, patent leather (Japanned leather) and special finishes for cotton and silk fabrics etc.

Commercial edible grade oil

The linseed oil is not edible because it contains high linolenic acid, a poly- unsaturated fatty acid, which makes the oil highly susceptible to oxidation as a result of which its drying property increases and gives a pungent flavour and rancidity. Further, the laxative properties of the mucilage in seed coat of the seed make the oil unsuitable for edible purpose. A number of new flax seed varieties, which are low in alpha-linolenic acid content (25-30%) have been identified in India. It produces high quality poly unsaturated edible oil developed through plant breeding techniques. Linola™ is the trademark for a new form of linseed in Australia developed in 1984 (Srivastava, 2009). These were specifically bred to produce edible oil, rather than for the traditional industrial use (Budwig, 1995). 'Solin' in Canada is another edible variety of linseed developed in 1990/91 (Srivastava, 2009). There are some farmers who are socially and economically forced to cultivate only linseed for years together. Some populations are there, who use only linseed oil for edible purpose. It is a basic need to develop linseed varieties with edible grade oil for these people. By the joint research efforts of Bhaba Atomic Research Centre (BARC) and All India Coordinated Research Project (AICRP) on linseed, five genotypes *viz*., TL11, TL 26, TL 27, TL36 and TL43 have been developed having less than 1% linolenic acid content (Srivastava, 2009). Further, a number of attempts have been made by induced mutation techniques to develop low linolenic acid types of seeds for edible purpose (Budwig, 1995). When the seeds were treated with chemical mutagens, varieties with less than 2% linolenic acid were developed. Linola oil is better than other edible oils such as sunflower, safflower and corn oil with regard to its composition of low saturated fatty acids (palmitic acid, 6%; stearic acid, 4%; oleic acid, 16% and high unsaturated fatty acid content linoleic acid, 72% and low unsaturated fatty acid content alpha linolenic acid, 2%). However, as edible oil, its prospects may not be progressive in comparision to traditional edible oils like Sun flower, Safflower and Soybean oil etc. (Nagaraj, 1995). Again, the residue (cake) left after extraction of oil from Linola seed is a valuable source of protein and energy for animal feeding. But with respect to its protein and carbohydrate composition, Linola cake is high in linoleic acid and low in linolenic acid. So linola cake can be used for cattle and horses wherever, linseed cake is currently used in animal feeding (Budwig, 1995).

Human consumption

Due to the presence of higher concentration of health promoting omega-3 fatty acids (alpha-linolenic acid), which lowers cholesterol level and imparts cardio vascular benefits, many linseed based recipes have been standardized. The crushed seeds/flour is used for value addition and for making various nutritious food preparations (Chauhan *et al.,* 2009). But the linseed oil is not edible due to the laxative properties of the mucilage in the seed coat and presence of higher level of linolenic acid which causes rancidity and emits pungent flavors on oxidation. So on a very small scale, it is used for edible purpose as flax seed breads, bagels and fried food stuff by a small segment of people (Anonymous, 2006). In Karnataka and parts of Maharashtra, linseed is used as a traditional food adjunct-chutney powder. It is also used as a medium of frying certain foods in Himachal Pradesh (Preethi, 2009).

Nutritional value

Linseed possesses many vital nutrients and nutraceuticals with promising health benefit for both human beings and animals. It contains eight essential amino acids, *viz.,* isoleucine, leucine, lysine, methionine, phenylanine, threonine, tryptophan and valine. It also contains carbohydrates, vitamins, minerals, crude fibre and this is the best herbal source of omega –3 and omega –6 fatty acids (Anonymous, 2006). Health experts prescribe these nutrients and other compounds for better health. One hundred thirty grams (one cup) of ground flax seeds give about 585 kcal energy, 26.0g protein, 53g total fat, high levels of dietary fibres (36.0g), total carbohydrate (38.0g) and all necessary vitamins, minerals for human body (Anonymous, 2003). So in recent years, it has attracted considerable interest due to its nutritional composition which has positive effects on disease prevention providing health beneficial components such as alpha linolenic acid, lignan and polysaccharides (Bozan and Temelli, 2008). Omega-3 fatty acid (alpha-linolenic acid) is a substrate for the synthesis of longer chain poly-unsaturated fatty acids mainly eicosapentaenoic and decosahexaenoic acids, which influence the biophysical properties of the cell membrane and are required for normal cell functions (Preethi, 2009).

As fodder

After the extraction of oil from the linseed seed, the residue left behind is called cake, which is brown in colour. Prior to defatting (to remove all or almost all), this cake contains 21.78% of non nitrogenous extract, 29.37% lipids and 27.78% protein, 7.02% fibre, 3.40% ash and 10.65% total humidity (Gutierrez *et al*., 2010). So it is a protein rich palatable feed for livestock. It is fed to the cattle to improve their health condition and to develop the gloss of their coat, although linseed meal is used as an additive in baking products (Coskuner and Karababa, 2007). However, linseed contain phytic acid, cyanogenicglucoside and goiterogen which limit the linseed cake as animal feed as these are anti nutritional factors. So meal or seeds should be properly processed to remove the toxic constituents.

Mucilage

Linseed mucilage which resides in seed coat is obtained by precipitation process from aqueous extract of seed (soaking in water for 24 hours) and gives high viscosity solution. It is a white fibrous mass and friable when fully dry and gives high viscosity solution when gets dissolved in water. It is a heterogeneous mixture of polysaccharides made up of xylose, glucose, galactose, arabinose, ramnoseand galacturonic acid. Taking the advantage of the physical properties of linseed mucilage as a water soluble emulsifier, thickener and binder, it is used as a thickener and emulsifier in food products. The potential application of linseed in foods as functional food stuff developed a great interest. The mucilage obtained from flax seed is very similar to gum arabic in its emulsifying properties (Coskuner and Karababa, 2007) and is comparable to guar gum in its capacity to bind water. Mucilage is used in cosmetic and pharmaceutical industries as ademulcent and as a useful base for eye ointment.

As fertilizer

Linseed oil cake is one of the best nitrogenous fertilizer among oilcakes with respect to nitrogen, phosphorus and potassium (4.7% N, 11.7% P_2O_5, 1.3% K_2O) contribution to soil (Anonymous, 2011b). It provides slow and steady nourishment, stimulation, protection from soil nematodes (particularly *Meloidogyne javanica*) and insects. So it also improves yields and quality of product like taste, flavour and amino acid composition etc. Moreover, it can also be used as a manure to prevent soil from unwanted microbes due to its germicidal properties by improving plant health and thereby gives greater resistance to infection (Anonymous, 2011b).

Composition of linseed seed

Seed is small, flat, oval, brown or yellow or deep brown coloured. The seed composition varies with variety, size, climate and maturity. The seed contains oil (36-48%),which is high in unsaturated fatty acid especially linolenic acid (Khan *et al*., 2010 and Rahimi *et al*., 2011) and about 6% mucilage, which resides in the seed coat. The seed has all essential components like crude fibre (5-10%), proteins (20.3%), fats (37.1%), minerals (2.4%), carbohydrates (28.9%), moisture (6.5%), calcium (170 mg/100 g), iron (370 mg/100g), carotene (2.7mg/100 g), thiamine (0.23 mg/100g), riboflavin (0.07 mg/100g), niacin (1.0mg/100g) together with wax, resin, phosphorus, sterols and small quantity of cyanogenic glucoside-linamarin (Nagaraj, 1995) and all essential amino acids such as isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine (Weiss, 1983). Though the aminoacid composition is similar to that of any other oilseed, it is rich in lysine and poor in methionine and the quality of linseed protein is better than that of other rapeseed proteins (Nagaraj, 2009). Flax seed contains atleast three types of phenolics such as phenolicacids (8-10g/kg), flavonoids (35-70mg/100g) and lignans (secoisolariciresinol diglucoside, SDG) about (1-26mg/g). Due to the presence of all vital elements of proteins, sugars, fats, dietary fibres to a sufficient level now a days, fried and powered seed is utilized in the preparation of day to day foods.

Linseed oil

The chief constituent of linseed seed is 30-45% oil. The oil is obtained by cold pressing (mechanical extraction with reduced heat, which is produced by rotational friction) has a golden yellow colour whereas a hot pressed oil (heat supply up to 200^0c) is yellowish brown. Freshly extracted oil is a viscid, distinct odour and bland taste.

Fatty acid composition of linseed oil

In the aliphatic chain of fatty acid, carboxyl end is called alpha and the methyl end is called omega. From the omega end there is double bond at 3^{rd} carbon called omega-3 and double bond at 6^{th} carbon called omega-6. Body of the human being cannot produce its own omega-3 and omega-6 fatty acids. So there is requirement of omega-3 and omega-6 rich food in the daily diet (Brenna, 2002). Linseed oil is a mixture of triglycerides. The different fatty acid constituents of triglyceride are triple unsaturated α- linolenic acid (an omega-3 fatty acid) (35-67%), saturated palmitic acid (4-16%), saturated stearic acid (0.3-10.0%), mono unsaturated oleic acid (13-38%) and double unsaturated linoleic acid (an omega 6- fatty acid) (7.0-18.0%).

Tocopherols, phytosterols (plant sterols) and campesterol

Tocopherols are a group of closely related fat soluble alcohols which behave like vitamin E. Natural tocopherols exits as a mixture of four homologous series such as α, β, γ and δ tocopherols. Linseed oil contains higher levels of β tocopherols (200 ppm) than α tocopherols (15-20 ppm) and γ tocopherols (5-7 ppm). Phytosterols (plant sterols) are the group of steroid alcohols present in linseed oil (about70 ppm). In addition to above, linseed oil also contains campesterols, which are the group of phytosterols and their chemical structure is similar to that of cholesterol (23-27 ppm). Due to the presence of higher levels of unsaturated fatty acids (more than 80% of the total fatty acids) and lower levels of α and γ tocopherol in linseed oil, the oil is highly unstable with limited shelf-life. So the oil gives bad frying smell (Nagaraj, 2009).

Medicinal value

Linseed seed contains omega-3 fatty acid in the form of alpha linolenic acid (ALA) which gives cardiovascular benefits by affecting prostaglandins and leukotriens which are related to blood clotting and inflammatory disorder like rheumatoid arthritis (Anonymous, 2005). Gamma linolenic acid found in flax seed showed tremendous effect in diabetics by normalizing the faulty fatty acid metabolism for diabetics. Linseed contains antibiotics called "Linatine" in its seed, which cures diseases for which no other medicine is effective (Anonymous, 2006). Flax seed contains both soluble and insoluble fibre. The soluble fibre can lower the blood cholesterol and insoluble fibre have laxative property which help to treat varieties of gastrointestinal conditions and provide health benefits for diarrhoea, constipation, irritable bowel syndrome (IBS) and inflammation in the lining of intestines. Linseed is one of the richest sources of lignans which are phytoestrogens, provide protection against certain forms of cancer (Morton *et al*., 1994). Flax seed sprouts induce apoptosis and inhibits cancer cell growth by demonstrating their anti proliferative effects in breast cancer cell (Lee, 2012). Recent reports (Adugna and Labuschagne, 2003 and Tripathi *et al*., 2013) indicate that consumption of linseed imparts numerous health benefits, including antihypercholesterolemic and anti-carcinogenic effects and is also beneficial in the development of brain and retinal tissues. Linseed oil may alleviate some cases of Alopecia Areata (hair loss) and facilitates weight loss in persons suffering from obesity. It is also useful in the treatment of some cases of Edema. Linseed oil is the only dietary oil allowed in the orthomolecular treatment (use of naturally occurring nutrients in maintaining health and treating disease) of Acquired Immune Deficiency Syndrome (AIDS) patients Further, this oil is useful in the alleviation of some cases of Pre Menstrual Syndrome (PMS) and makes pregnancy less eventful, make deliveries easier and produces healthier offsprings (Tripathi *et al*., 2013). Linseed tea, which is prepared by boiling 1 part of linseed seed with 20 parts of water till grains are soft, is used as a demulcent in respiratory irritation and in intestinal or urinary catarrhs (Vajpeyi *et al*., 2005). The anti-microbial activity of linseed oil and its therapeutic efficacy in bovine mastitis (inflammatory disorder) has been reported recently (Kaithwas *et al*., 2011). Linseed oil is recommended for the treatment of piles. It is also used as a base for different cosmetic and pharmaceutical products. Linseed oil is traditionally used in various skin infections externally as a soothing application for burns, wounds, acne, eczema, psoriasis and boils. This oil is available in the form of *Arectal oil* prepared by equal quantity of lime water with linseed oil (David and Toms, 2006) for various skin treatments. Linseed oil is used as a carrier of vitamins and irritant drugs. Crushed linseed is used in the form of poultice, which is prepared by boiling 28g linseed seeds in 72ml of water. Before its application it may be sprinkled with boric acid. Cough syrup in the name of 'Mucilage lini' is prepared from the mucilage of linseed taking 1 part of mucilage with 8 parts of water.

Linseed oil used as surface treatment materials

Boiled linseed oil is one of the widely used surface treatment materials for protection of concrete structures (Pfeifer and Scali, 1981). It can be used either in the form of solution or emulsion. The solution is prepared by taking linseed oil and mineral sprit with the proportional ratio ranging from 90:10 to 30:70, but commonly used ratio is 50:50. In order to accelerate the dryness of the oil, some dryers such as cobalt, manganese, lead salts or naphthenic acids are often added to the solution. Another type of linseed solution is available taking 50% linseed oil with 50% kerosene. On the other hand, in a linseed oil emulsion equal volume proportions of oil phase is added with water phase (Xie *et al.,* 1995).

Development of linseed varieties with good fibre quality

Now-a-days, eight double purpose linseed varieties (oil and fibre) have been developed. These are Gaurav, Jeevan, Nagarkot, Shikha, Rashmi, Meera, Parvati and Pratap Alsi-1 (Srivastava, 2009). The productivity of oil (1200-1600kg/ha) and fibre (860-1200kg/ha) of these developed varieties are better than traditional varieties. The disease resistance of these varieties are high but the quality of fibres collected from the available varieties are inferior in comparison to imported fibres from European countries which are used in our country for defense and industrial purposes (Srivastava, 2009). So, more research work is to be initiated to improve the quality of fibre by breeding/agronomic manipulations, which would save 35 crores of rupees foreign exchange and will generate more employment.

Characteristics of flax fibre

Flax fibres are an interesting alternative to mineral fibres due to its low cost, low density, high specific stiffness and recyclability nature. These constitute for their use as rigid composite materials (Baley, 2002).

Composition of flax fibre

According to Batra (1998), flax fibre is composed of cellulose (64.1%), hemicellulose (16.7%), pectin (1.8%), lignin (2.0%), water soluble compounds (3.9%), wax (1.5%) and water (10.0%). However, these compositions are relative to the variety of plant, soil quality, weathering conditions, the level of plant maturity and the quality of retting process etc.

Structure of flax fibre

The detailed structure of flax fibre cell reveals that it consists of two cell walls viz. primary cell wall (0.2µm thick) and secondary cell wall. They are arranged in a concentric cylinders with a small channel in the middle called lumen, through which uptake of water continues. The main core of the fibre is contributed by secondary wall, which is designed as S_1, S_2 and S_3, from which S_2 is the main bulk of the fibre (Fig.1 and Fig. 2). Again it has been found that the flax fibre is strengthened by the highly crystalline cellulose fibrils which are spirally arranged in a matrix of amorphous hemicellulose and lignin (Fig.3). Each fibre is made up of macrofibrils, microfibrils and elementary fibrils. Macro fibrils are 0.5mm in diameter and are an assembly of microfibrils, which are 10 to 20 nm in diameter, which in turn are an assembly of up to 20 elementary fibrils called micelles. Each micelle is made up of 50 to 100 molecules of cellulose. The distance between two micelles is about 01 nm and about 10nm between two microfibrils (Baley,2002).

Cultural methods

Linseed is purely a *rabi* and cool season crop, which requires moderate to cool temperature during the growing season. This is generally confined to low elevation, and the plains. It can grow where annual precipitation ranges from 48-76 cm. If the crop is exposed to drought and high temperature (about 32°C) during and after the flowering stage, the yield, size and oil content of seeds are greatly reduced. Linseed also grows on marginal and sub-marginal rainfed soil, which may vary from light to heavy soil. When the plants become golden yellow the capsules turn brown and seeds in the capsules rattle (Plate 4). This is the appropriate time to harvest. In an irrigated field, the crop can produce seed yield of 12-15 q/ha.

Diseases with causal organisms and symptoms

Disease is one of the major constraints that limit productivity of linseed. The linseed crop is infected by all classes of pathogens *viz*. virus, bacteria, fungi and nematodes. There are a number of diseases to which linseed is exposed. But rust, wilt, *Alternaria* blight and powdery mildew are the major ones causing losses up to 80-100%, 80%, 27-60% and 60% respectively (Anonymous, 2005).

Rust *(Melampsora lini)*

Rust disease appears in the form of bright- yellow or orange coloured uredia on the leaves, stems and capsules. Uredia are generally circular on leaves and elongated on the stems and converted to pustules. Later the entire plant becomes covered by yellow-orange pustules. The disease commonly affects stem but more severely leaves, which die prematurely.

Wilt (*Fusarium oxysporum f. lini*)

Wilt is one of the most serious diseases in linseed causing a great loss. It develops in all the stages of their growth of the plants. Infection in seedling stage mostly causes falling off cotyledons. In the growth stage, dark green or brownish spots appear and these leaves shrivel. Infected plants ripen prematurely and develop black colouration of the vascular tissue in the stem and root of the plant. The dead and defoliated plants conspicuously appear in the field.

***Alternaria* blight** (*Alternaria lini and Alternaria linicola*):-

All aerial parts of the plants are severely infected which causes heavy damage to the crop. However, disease appears on the floral parts particularly near the calyx in the form of small dark brown lesions. But on the young leaves, these lesions are large and extend to the stem. Later such leaves dry up and get twisted. Severely infected plants dry up by giving a burnt appearance in the field.

Powdery mildew (*Oidium lini*):-

The major symptom of this disease is the appearance of superficial whitish colonies of pathogen on the aerial parts including floral buds.

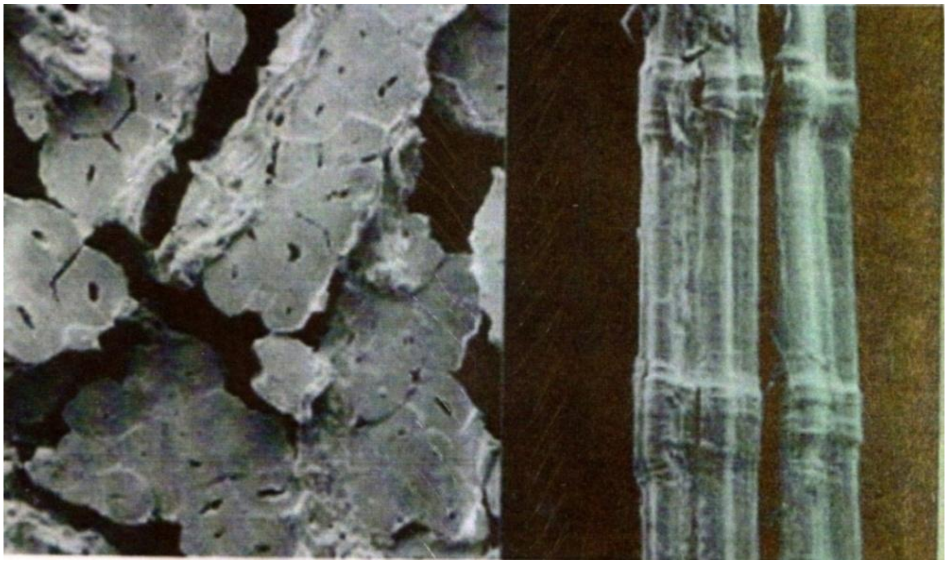

Fig.1: Structure of flax fibre cell under microscope.

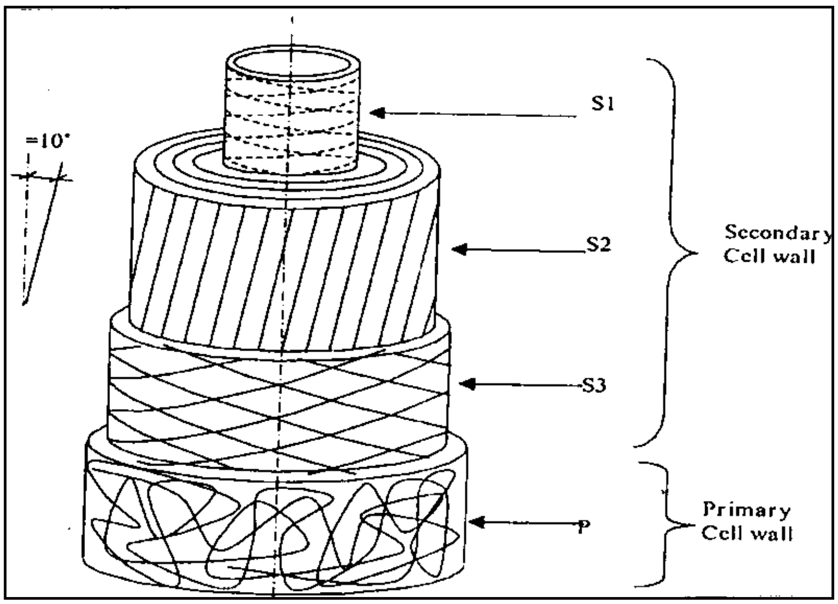

Fig.2: Characteristics of flax fibre.

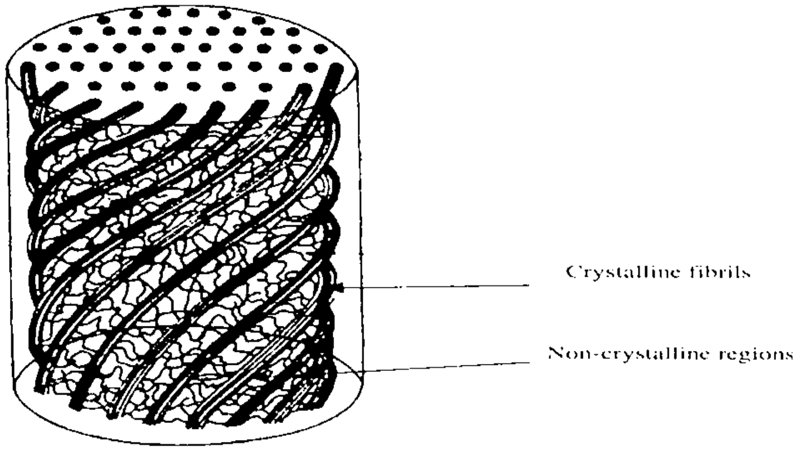

Fig. 3: Matrix of amorphous hemicellulose and lignin.

Plate 1: Plant types in respect to height and colour of flower; **a**. Bushy (Bushy branching); **b**. Semi erect (Lateral Branching); **c.** Red colour flower of linseed with Semi erect (Lateral Branching); **d.** Long erect (top branching)

Plate 2: Shape of flower; **a.** Funnel shape; **b.** Disc shape; **c.** Star shape; **d.** Tubular shape

Plate 3: Flowering and fruiting of linseed plants; **a.** Individual flower with five petals; **b.** Fused stamens; **c.** Number of flowers in a plant; **d.** Capsules bearing seeds of *Linum usitatissimum* L. plant

Plate 4: Field preparation and cultivation; **a.** Field shows pre-seed germination/starting of seed germination; **b.** Seedling stage observed from field; **c.** Linseed plants bearing a number of flowers in the erect branches. **d.** Matured capsules ready to harvest

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