Genetic Resources of Linseed (*Linum usitatissimum* L.) – Conservation and Utilization in Crop Improvement

J Radhamani[1], SD Dubey[2], RL Srivastava[3] and AK Singh[1]

[1] *Division of Germplasm Conservation, National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 012*

[2] *ACRIP on Linseed, Kanpur, Uttar Pradesh*

Linseed is one of the important oilseed and fibre-yielding crops of India. India is the third largest producer in the world. However, the average national productivity (403 Kg/ha) is far below the world average (851 Kg/ha), predominantly owing to the susceptibility of the cultivars to biotic and abiotic stresses. With the inception of Coordinated Research Project on linseed significant progress has been made in the varietal development. The development of about 56 high yielding, disease resistant varieties suitable for different agro-climatic zones has helped in improving not only the productivity but also addressing various biotic and abiotic stresses. Resistant sources have been identified for the disease like rust [*Melampsora lini* (Pers.) Lev.], wilt (*Fusarium oxysporum* f. *lini*), powdery mildew (*Oidium lini* Skoric), leaf spot (*Alternaria lini* Dey) and pests such as linseed gall midge (*Dasyneura lini* Barnes) and linseed semilooper (*Plusia orichalcea* Fabr.).Nevertheless, due to narrow genetic base of the released varieties, concerted efforts are required to breed varieties involving distant and exotic germplasm, preferably from main centres of diversity, to produce varieties with higher level of resistance and productivity. Present paper deals with the status of varietal germplasm and sources of resistance available for the effective utilization of linseed germplasm at National level.

Key words: Genetic resources, Germplasm, Varieties, Linseed/flax, *Linum usitatissimum*

Linseed or flax (*Linum usitatissimum* L.) is an annual oilseed crop of the family Linaceae. Genus *Linum* has nearly 100 species and over 200 varieties. Depending on the agro-climatic conditions there is a diverse range of variability in the crop in height (25 to 125 cm), branching pattern (sparsely and heavily branched) and maturity periods (fast-growing varieties spread in the north latitudes and mountainous regions to slower-growing varieties cultivated on irrigated soils in Asia). Commercially grown flax varieties/cultivars are grouped into two main types-fibre flax and seed flax, the former is generically referred to as long-stalked flax and the latter as crown flax. Long-stalked flax is grown for fibre and cultivated as a spring crop on primarily silt or clay loams in a moist and warm climate.

India ranks third largest producer amongst the linseed-producing countries. Germany has the highest productivity (1699 Kg/ha) followed by UK (1258 Kg/ha), Canada (1078 Kg/ha) and China (933 Kg/ha), whereas India averages 403 Kg/ha. It occupies an important position in India for its technical grade vegetable oil producing property. The acreage of linseed in India is nearly 5.26 lakh/ha with production of 2.12 lakh tones and national productivity is about 403 Kg/ha as per the 2003-04 records. Fibre yielding property from the linseed stalk is an added advantage of this crop. In India, Madhya Pradesh leads in yield and acreage, followed by Uttar Pradesh, Maharashtra, Chhattisgarh, Bihar, Jharkhand, Karnataka and West Bengal. In India *Linum usitatissimum* is the main cultivated species. However, for the ornamental purposes, species like *L. gradiflorum*, *L. mysorense*, *L. perenne*, *L. strictum*, *L. angustifolium*, and *L. bienne* are occasionally grown in gardens. Distinct morphological features such as flower colour, seed size, plant and capsule type have been observed in different species.

Origin and Distribution

Flax is believed to be one of the most ancient agricultural crops. It is distributed throughout the world but it was never found with certainty in wild state under natural conditions. A number of workers (Planchen, 1848; Decandolle, 1904; Helbock, 1956; Richharia, 1962; Gill, 1966; Smith, 1969) have attempted to trace the origin and history of *L. usitattisimum*. It is recognized to be an old world crop and as revealed by historical and archaeological records, its cultivation was in practice long before Christian era in Europe, Africa and Asia. There seems to be no certainty about its actual time of domestication.

* *Corresponding author's E-mail: jalliradhamani@yahoo.co.in*

Domestication of fibre flax occurred in India and China more than 5,000 years ago. There is evidence that as far back as 3,000-4,000 years BC flax was grown for fibre in Mesopotamia, Assyria and Egypt where the finest linen cloths were spun. Flax was extensively raised in Colchis that used linen to pay tribute to the Turks. According to one account, the voyage of Argonauts from Hellas to Colchis for the Golden Fleece was in fact prompted by a desire to obtain the secret of making fine flax yarn that was treasured as much as gold and was as good as that produced in Egypt.

It is, however, generally believed that linseed originated in an area east of the Mediterranean sea, near India (Simmonds, 1976). Seed type linseed, cultivated for its oil, is believed to have developed primarily in South-eastern Asia, whereas fibre flax developed in the Mediterranean region. Botanically, these two forms are in no way different from each other. The names viz. linseed and flax are used interchangeably. There is a great variation in flax found in India and adjacent northern area. The most likely progenitor is *L. angustifolium*, but other species such as L. *bienne* also seems to have contributed in the evolution of cultivated linseed (Gill, 1987).

Morphology and Cultivation

The cultivated plant (*Linum usitatissimum* L.) has a short tap root system with fibrous branch, which may extend to a depth of 9-120 cm. in favourable soil texture. Linseed is grown in the range of latitudes between the 10^{th} and 65^{th} parallels, both north and south. Areas with the annual rainfall ranging from 45-75 cm are best suited for its cultivation. The seed crop does well under moderate cold, but the fibre crop grows best in cool moist climates. In India, the crop is grown in the *rabi* season from September-October to February-March. Linseed can be grown on different kinds of soils, except the sandy and badly drained heavy clays or clay loams. The crop is grown either broadcast or drilled in lines 20 to 30 cm apart. Harvesting is done when the crop ripe with a sickle or by uprooting the plants. When the fibre is also desired along with seed, the harvesting of the crop is done at the stage of capsule maturity even when the crop is slightly green. The fruit is near rounded capsule of about 5-10 mm in diameter covered by persistent sepals. Mature capsule is non-dehiscent. The seeds are oval, lenticular, smooth, shining and pointed at one end measuring 4-6 mm length and 2-3 mm breadth. The seed colour varies from pure yellow, yellowish with brownish tinge, deep fawn and light fawn, light brown to deep brown.

Economic Importance

Linseed occupies a greater importance among oilseeds, owing to its various uses and special qualities. In India, it is grown mainly for extracting oil. The oil content of the seed varies from 33 to 47 per cent. Linseed oil is not suitable for edible purpose because of its high alpha-linolenic acid concentration (Frankel, 1991). However, it is precisely this characteristic that makes linseed oil unsurpassed as a drying oil for manufacturing paint and varnishes, oilcloth, waterproof fabric pad and printing inks, leather and soap industries and linoleum as edible oil in some areas, varnishes, printing inks, etc. (McHughen, 1992). Successful breeding through mutagenesis led to the development of linseed mutants with seed oil containing less then 2 per centalpha-linolenic acid (Green, 1986, Rowland and Bhatty, 1991). Such an oil is of great value for edible purposes (Bickert et al., 1994). Gamma- linolenic acid is a polyunsaturated fatty acid that attracts much interest because of its many health benefits (Fan and Chapkin, 1998). Research indicates several possible human health benefits associated with consumption of flax oil. Flax contains approximately 20 per centalpha-linolenic acid (ALA, DM basis), an essential omega-3 fatty acid that is a precursor for eicosapentaenoic acid (EPA), which in turn is a precursor for the formation of eicosanoids. Eicosanoids are hormone-like compounds that play an essential role in immune response. Seed is a bowl cleaning fibre and act as an anticancer agent effective in colon, prostrate and breast tumors. Linseed-cake is a very good manure and animal feed. Linseed straw produces fibre of good quality. Linseed is used in making paper, strong twines, canvas, house pipe (water storage tubs), suiting-shirting and various indispensable products for aerospace, aeronautical and defense purposes. Rough and strong fibre is used to make low cost roofing tiles based on convertible plastics of unsaturated polymers.

Genetic Resources

Germplasm accessions are supposed to be the library of the variable plant cultures of a particular crop. In any systematic breeding programme, for improving a crop with respect to desired trait(s), potential donor/ lines are the prerequisite. The main objective behind the evaluation is to isolate the potential donors for their effective utilization in subsequent breeding programmes

for creating genetic variability for yield and yield components.

Due to wide range of variability in different traits exist in linseed, worldwide exploration, collection, evaluation and maintenance are prevailing for linseed germplasm. Linseed germplasm is currently being maintained at 38 centres in 28 countries. Major holding having more than 200 accessions are located in Russian Federation (5240), China (4886–3 centres), Romania (3701–3 centres), Ethiopia (3110), Germany (2763–3 centres), Czech Republic (2032–2 centres), Argentina (1125), Ukraine (1064–2 centres), Poland (547), Sweeden (357) and Japan (287) (Tiwari, 2002). The countries with more than one center have duplicates in the holdings at different centres. In India a number of landraces and exotic germplasm were collected from different states/ districts and from different countries through National Bureau of Plant Genetic Resources, New Delhi.

A total of 2,730 accessions are being maintained at All India Coordinated Research Project on Linseed under Indian Council of Agricultural Research Kanpur, in India comprising 2,180 of indigenous and 550 of exotic collections. While at National Gene Bank, New Delhi, a total of 2,365 accessions are maintained which has more than 2,242 collections predominantly of indigenous and 123 of exotic collections. About 85 per cent of the total collection represents the landraces and traditional varieties originated in different agro-climate or production systems. Besides others centres *viz.* Mauranipur (1300), Raipur (440), Kanpur (387), Nagpur (251), Hoshangabad (146) and Jashipur (107) also have active germplasm collections.

Efforts towards Varietal Development

In India, linseed is used for both oil and fibre so breeding for dual purpose in linseed is essential. A huge quantity of quality straw is wasted as fuel. If acceptable, fibre in appreciable quantity is introduced in the variety producing seed for oil purpose there would be high demand for dual purpose varieties in the market. Incorporation of genes for resistance to insect pests and disease is also a desirable objective as this causes substantial loss in yield. Development of early maturing and fertilizer responsive cultivars may cause a breakthrough in linseed cultivation in India since a considerable amount of yield loss has been observed in shedding of flowers and capsules in the late flowering varieties due to high temperature in the later period of growth.

With the inception of Coordinated Research Project on linseed in the country, number of high yielding seed types and dual purpose varieties have been developed viz. Gaurav, Meera, Shikha, Rashmi, Nagarkot and Parvati (Table1). Double purpose varieties can compete well with other crops. The seed Act, 1966 and the Central Sub-Committee on Crop Standards, Notification and Release of Varieties in Agricultural Crops have played a great role in bringing out varieties developed in various crops in public domain and recognition to the role of seed quality in seed production to increase crop productivity. In the initial stage of crop improvement i.e., before 1967, the improved cultivars were selected from the local populations/landraces and resulted in the release of only ten varieties. This particular trend continued until 1980 with very little efforts of breeding in varietal development and consequently, 32 cultivars were released before 2,000 but the average productivity remained stagnant until mid eighties because of poor production technology and the susceptibility of released cultivars to various biotic/abiotic stresses. This demanded breeding for resistance, involving screening of germplasm for identification of sources and hybridization breeding for incorporation of gene(s) conferring resistance.

Although, development of cultivars for higher yield initially received more attention of breeders, but later cultivars coupled with tolerance for some of the biotic stresses were also developed. A significant progress has been made in this regard and about 56 varieties have been released, so far as a result of the efforts of All India Coordinated Research Project, State Agricultural Universities or State Agricultural Departments. Amongst the 56 released varieties 13 are the state released and 43 are released under Central Variety Release Committee at National level (Table 1). Most of them have been notified under the Section 5 of the Seeds Act. It is evident that there has been a major thrust for the development of early maturing and high yielding varieties. Of the total 56 varieties developed at national level, 46 varieties have been developed through pedigree selection and 10 varieties through mass selection. About 11 per cent of varieties released have exotic germplasm in their parentage. Exotic germplasm has not been of much use as they are poor yielder compared to the indigenous, late maturing, small seeded and tall plants. Similarly wild species were also not used in varietal improvement due to their cross incompatibility, hybrid in-viability, hybrid sterility and transfer of undesirable

genes. The oil content of the varieties ranged from 40-45 per cent.

Abiotic/ Biotic Stresses

For sustainable improvement, there is an urgent need for introduction of accessions with resistance to newly arising biotic and abiotic stress. Wilt, leaf spot, powdery mildew and rust are the major diseases of linseed and have been recorded from all the linseed growing areas. Rust infection not only damages the fibre and reduces the yield but also is reported to cause significant reduction in oil content. In wilt the plants are attacked at all stages of growth. Leaf spot is found to cause heavy damage to crop particularly in low lying ill drained areas and the powdery mildew occur mainly in the crop grown in rich soils under irrigated conditions.

Linseed budfly (*Dasineura lini*) is the most serious pest of linseed. Sometimes indigo caterpillar (*Spodoptera exigua*) and thrips (*Caliothrips indicus)* also cause substantial damage. Parasitism of linseed budfly by pteromalid larval parasitoid Habrocytus fasciatus goes up to 23 per cent (Anand Prakash and Chaturvedi, 1978), *Systests dasyneurae* is also a key parasitoid of linseed budfly. The most effective method to control the disease is to cultivate the resistant varieties. The growing of early varieties and mixed cropping are reported to reduce the incidence of the pest. In linseed *Alternaria* blight is the most serious diseases and bud fly is a major pest and both are treated on major thrust. A special screening under saline/alkaline soils has led to the identification of resistant lines.

The yield potential of varieties was found to be 800-1000 Q/ha under rainfed and 1500-2000 Q/ha under irrigated conditions. Some of the varieties such as RLU-6, NL-142, Neelum, Shekar, Parvati, RL-914, Suyog, BS-44 showed significantly higher yields (≥ 15 Q/ha, Table 1). Although K-2, Neelum and T-397 varieties were released 25-30 years ago yet are under commercial cultivation due to their higher yield percentage. On the other hand some of the state released varieties, which have lower yields were highly resistant to pests/diseases. Unlike other crops most of the varieties have a high degree of mono or multiple disease resistance. A number of high yielding and wilt resistant varieties are available such as NP (RR) 9, BS 44, Hira, Mukta, Neelum and Jawahar Linseed-23 (Table 1). Some of the varieties were mono disease resistance such as C-429 and Jawahar-17 are rust resistant and others are multiple disease resistant. Gaurav, Binwa, Baner, BS-44, Jawahar-1, M-10 and Mayurbhan are both rust and wilt resistant. Similarly, Jeevan, Sheela, RLC-81, Meera, Rashmi, Shubra, Shikha, Laxmi-27, Nagarkot and chambal alsi are resistant to all three diseases-rust, wilt and powdry mildew. Whereas Nagarkot, RLC-76, Shikha and RLU-6 were found to be resistant to all rust, wilt, powdery mildew and *Alternaria* blight (Table-2). Varieties LC-185, Jawahar-552 and Jawahar-7 were found suitable for *Utera* cultivation. Although several Institutes from different states *viz.* Himachal Pradesh, Maharashtra, Rajasthan and Punjab had contributed for the development of linseed varieties, the maximum number of linseed varieties have been released from Kanpur, Uttar Pradesh (29 per cent).

Very few accessions have been used for transfer of specific desirable traits. Eighty per centof the varieties have been developed predominantly using local collections, where selections from introduced germplasm has been the main breeding methodology. Therefore, for sustainability and to increase the yield, greater emphasis is required for exploitation of germplasm, primarily exotic to breed resistance to yield reducing factors and specific agronomic traits so that varieties for specific environment and requirement can be developed. The improved varieties recommended for cultivation in different zones are listed in Table 1.

The growing of resistant varieties is recommended to control these diseases (Table 2). On saline soils Hira and Mukta performed better than others (Rai and Sinha, 1980). Therefore, there is a need for incorporation of new, diverse and more stable sources of resistance and other desirable features, including wild species in the parentage.

Future Perspectives

Incorporation of resistance against stresses in combination of desirable commercial characteristics and widening of genetic base of the cultivars is an important challenge. In this regard, extensive hybridization with exotic sources and wild species provide a unique opportunity some of which have low linolenic acid (edible grade oil with 8% linolenic acid) viz.. *L.sulacatum* (3%), *L. mucronatum* (3%), *L. salsoloids* (3%), *L. suffruticosum* (3.5%), *L. tenuifolium* (6.3%). Approaches to confer resistance to bacteria, nematodes and herbicides are enumerated in the recent reviews. Considerable research is needed to apply these tool and techniques to manage biotic stresses such as development of elite breeding lines resistant to *Alternaria* blight and bud fly and to abiotic

Table 1. List of Linseed varieties released from Indian Agricultural Research System till date

Variety	National Identity	Pedigree	Developing Institute	Developer	Notification No.	Adaptation Zone*	Yield Q/ha	Specific trait(s)	Additional trait (s)
Laxmi 27 (LMH-27)	IC113105	Neelum/KP-1//Neelum/NP(RR)-9///Neelum/R-1//Neelum/Afg-8	Chandra Shekhar Azad University of Agriculture & Technology (CSAU&T), Kanpur, UP	Dr. S.L. Katiyar	165 E , 06.03.1987	III	13	Resistant to rust, wilt and Powdery mildew	Deep brown seeds, Suitable for rain fed and irrigated conditions, Oil Content 45%
Sweta (LHCK-131)	IC113107	Mukta/T-1206	CSAU&T, Kanpur, UP	Dr. R.N. Dubey	540 E, 24.07.1985	II	9	Resistant to drought, frost, Non shattering, Resistant to rust	Plant erect, Suitable for late and early sowing, Oil content 44%
Shubhra (LHCK-21)	IC113108	Mukta/K-2	CSAU&T, Kanpur, UP	Dr. R.N. Dubey	540 E, 24.07.1985	II	12	Resistant to rust, wilt & powdery mildew	Erect growth, white flowered, brown seeds, Oil Content 45%
Neelum	IC113109	T-1/NP(RR)-9	CSAU&T, Kanpur, UP	Dr. N.K. Bajpai	13 , 19.12.1978	II, III	15	High yielding	Double purpose variety, Oil content 43%
T 397	IC113110	T-491/T-1103-1	CSAU&T, Kanpur, UP	Dr. L.C. Gangwar	596 E, 13.08.1984	II	9	Tolerant to rust & wilt	Errect tall, Used as national check and Oil content 44%.
Gaurav (LCK-152)	IC113111	Sel-3/EC-1552	CSAU&T, Kanpur, UP	Dr. R.N. Dubey	834 E, 18.09.1987	II	11	Resistant to rust and wilt	Tall plant, bold seeds, Fawn colour seeds, Double purpose variety, Oil content 43%
LC- 54	IC113155	K-2/Kangra local	Punjab Agricultural University (PAU), Ludhiana, Punjab	Dr. T.R. Gupta	19E , 14.01.1982	I	12	Resistant to rust, Powdery mildew & tolerant to Alternaria blight, Tolerant to frost	Errect growth habit with white flowers, Medium size seeds, Oil content 42%
LC-185	IC113156	NP(RR)-37/ Kangra Local	PAU, Ludhiana, Punjab	Dr. T.R. Gupta	44 E, 21.08.1975	I	8	Tolerant to frost, Suitable for *Utera* cultivation	Short stature plant, yellow seeds
Parvati (LMH-16-5)	IC305053	EC41628//// EC77959// (DPL-20// Neelum) (EC-216/Hira)/ (/BR-1/ NP-440)	CSAU&T, Kanpur, UP	Dr. P.K. Singh	92 E , 02.02.2001	II, III	16	High yielding, Resistant to rust & Powdery mildew, Early maturity	Medium plant height, non-shattering capsule, Dull yellow seeds, Double purpose variety, Oil content 42%
Shekhar (LCK-9313)	IC305055	Laxmi-27/ EC-1387	CSAU&T, Kanpur, UP	Dr. Brahm Singh	92 E, 02.02.2001	II	16	High yielding, Resistant to owdery mildew, Prust & wilt	Shiny brown seeds, Oil content 43%
NL-97	IC305109	R-7xRLC-4	Mahatma Phule Krishi Vidyapeeth (MPKV), All India Coordinated Research Project on Oil Seeds , Jalgaon, Maharashtra	Dr. S.K. Raut	92 E, 02.02.2001	III	6	Resistant to Powdery mildew, wilt, Alternaria blight & Bud fly, Earliness	Brown seed colour, Oil content 42%

Variety	National Identity	Pedigree	Developing Institute	Developer	Notification No.	Adaptation Zone*	Yield Q/ha	Specific trait(s)	Additional trait (s)
Binwa (KL-210)	IC420772	Flak-1x SPS-47/7-10-3	Ch. Sarwan Kumar Krishi Vishwa Vidyalaya (Ch.S.K.H.P.K.V), Palampur, HP	Dr.(Mrs.) Bhataria	State. O.122 (E), 02.02.2005	I	9	Resistant to rust and wilt	Purplish blue flowers, yellow seeds, Oil content 40%
Baner (KL-224)	IC420773	EC-21741x LC-216	Ch.S.K.H.P.K.V, Palampur, HP	Dr.(Mrs.) Bhataria	State. O.122 (E), 02.02.2005	I	5	Resistant to rust and wilt	Purple flower, brown seeds, Oil content 39.29%
Kiran (RLC-6)	IC426925	Afg-8/R-1//Afg-8	Indira Gandhi Krishi Vishwa Vidyalaya (IGKVV), Raipur, Chhattisgarh	Dr.S.K. Agrawal	10 E, 01.01.1988	II,III	8	Resistant to rust, Powdery mildew & wilt	Medium plant height and seed size, Oil content 43%
Jawahar-552 (R-552)	IC426926	No.55/B-67	IGKVV, Raipur, Chhattisgarh	Dr.S.K. Agrawal	596 E, 13.08.1984	III	9	Resistant to wilt, suitable for *utera* cultivation	Brown and bold seeds, Oil content 44%
Sheela (LCK-9211)	IC426928	Gaurav/Janki	CSAU&T, Kanpur, UP	Dr.R.N. Dubey	92 E, 02.02.2001	I	14	Resistant to rust, wilt & Powdery mildew, Early maturity	Shiny brown seeds, Oil content 41%
Rashmi (LCK-9216)	IC426929	Gaurav/Janki	CSAU&T, Kanpur, UP	Dr.R.N. Dubey	1050 E, 26.10.1999	II,III	10	Resistant to rust, wilt & Powdery mildew	Brown and shiny seeds, Double purpose variety, Oil content 41%.
Garima (LHCK-39)	IC426930	T-126/Neelum	CSAU&T, Kanpur, UP	Dr.R.N. Dubey	540 E, 24.07.1985	II	14	Resistant to rust, wilt and bud fly	Brown seeds, Oil content 42%
Padmini	IC426932	EC41628/ EC-77959// DPL-20/ Neelum	CSAU&T, Kanpur, UP	Dr. P.K. Singh	1050 E, 26.10.1999	III	9	Bold seeds with high oil content	Brown seeds, Double purpose variety, Oil content 43%
Nagarkot (KL-31)	IC426935	New River/ LC-216	Ch.S.K.H.P.K.V, Palampur, HP	Dr.(Mrs.) Bhataria	408 E, 04.05.1995	I, II, III	12	Resistant to rust, wilt, Powdery mildew and tolerant to Alternaria blight.	Moderate tillering, Bold and brown seeds, Double purpose variety, Oil content 43%.
Surabhi (KL-1)	IC426936	LC-216/LC-185	Ch.S.K.H.P.K.V, Palampur, HP	Dr. (Mrs.) Bhataria	408 E, 04.05.1995	I	10	Early maturity, Resistant to rust & wilt	Medium and yellow seeds, Oil content 44%
Meera (RL-933)	IC427794	RL-75-6-2/ RL-298// LCK8528	MPUA & T, Udaipur, Rajasthan	Dr. C.S. Dubey	340 E, 03.04.2000	II	14	Resistant to rust, wilt & Powdery mildew.	Brown seeds, Double purpose variety, Oil content 42%.
RLC 81 (Indira Alsi-32)	IC449071	Kiranx Ayogi	IGKVV, Raipur, Chhattisgarh	Dr. S.S.Rao	29.06.2005	III	8	Resistant to rust, wilt & Powdery mildew, Early maturity.	Dark brown seeds, Oil content 39.29%
RLC 76 (Kartika)	IC512310	Kiran/ LCK 88062	IGKVV, Raipur, Chhattisgarh	Dr. S.S.Rao	29.06.2005	III	8	Early maturing, moderately resistant to rust, wilt & Alternaria blight and resistant to Powdery mildew	Oil content 42.9%

Variety	National Identity	Pedigree	Developing Institute	Developer	Notification No.	Adaptation Zone*	Yield Q/ha	Specific trait(s)	Additional trait (s)
Him Alsi-1	IC520864	K-2XTLP-1	Ch.S.K.H.P.K.V, Palampur, HP	Dr.S.Bhateria	–	–	14	Bold seeds, good yield	
Him Alsi 2	IC520865	NA	Ch.S.K.H.P.K.V, Palampur, HP	Dr.s.Bhateria	–	–	13	Bold seeds, good yield	
NL-142	IC523094	R7XRLC-6	Dr.PDKV, Akola, Nagpur, Maharashtra	DR.P.B. Ghorpade	State, 2004	III	15	High yielding, Earliness, resistant to Powdery mildew and Bud fly	Oil content 41.36%
Hira	IC523799	H-342/NP(RR)-9	CSAU&T, Kanpur, UP	Dr.N.K.Bajpai	429 E, 19.12.1978	II	10	Non shattering and bold seeds	Medium tall plant, spreading, moderate tillering, white and light blue flowers, Brown and Bold seeds, Denotified
Mukta	IC5237800	H-626/NP(RR)I-9	CSAU&T, Kanpur, UP	Dr.N.K.Bajpai	429 E, 19.12.1978	II	12	Medium yield with bold seeds	Errect basal branching, Denotified
Neela	IC5237801	Local selection from WB	Pulses & Oilseeds Research Station, Berhampore, WB	Not available	19 E, 14.01.1982	II	9	Tolerant to rust & wilt	Medium, brown seeds
Chambal Alsi	IC5239802	Local/RR-45	MPUA&T,Udaipur, Rajasthan	Dr.P.K.Dixit	13, 19.12.1978	III	12	Tolerant to wilt, rust & powdery mildew	Moderately spreading type, non dehiscent fruit, brown and bold seeds
Himalini (LC-45)	IC5239803	K-2/Kangra local	Ch.S.K.H.P.K.V, Palampur, HP	Dr.N.D.Rana	295 E, 09.04.1985	I	13	Resistant to rust, wilt and bud fly, Early maturity	White flowers, Brown seeds, Oil content 42%.
Jawahar-23	IC5239804	EC-9832/Heera	All India Co-ordinated Research Project on Sesame & Niger (JNKVV), Jabalpur, MP	Dr.S.R.Srivastava	540 E, 24.07.1985	III	9	Tolerant to lodging, frost, Non shattering, Resistant to rust, wilt	White flowers, Synchronous flowering and fruiting, Brown seeds, Oil content 43%
RL-914	IC5239805	RR-9/R-93/ FLAK1/LC54	Maharana Pratap University of Agriculture &Technology, Udaipur, Rajesthan	Dr. (Mrs.)Veena Bhatanager	937 E, 04-09.2002	III	16	Resistant to Powdery A mildew, wilt, Iternaria blight	Errect branching, oval capsule
Suyog (SLS-27)	IC5239806	(KiranxKL 168) Kiran	JNKVV, Jabalpur, MP	Dr. S.K.Madaria	8161 E, 04.02.2004	III	15	High yielding, Resistant to rust, wilt, Powdery mildew and Bud fly	White flower, light brown seed, Oil content 41.43%
LMS-4-27	IC5239807	Shubra/J1//J1/Kiran	C.S.A.U., Mauranipur	Dr. V.P. Nagaich		III	8	Resistant to wilt, Powdery mildew and Bud fly, Early maturity	Oil content 41.10%
Shikha (LCK-8528)	IC5239808	Hira/CRISTA	CSAU&T, Kanpur, UP	Dr.R.N.Dubey	647 E, 09.09.1997	II	12	Resistant to rust, wilt & tolerant to Powdery mildew & Alternaria blight	Brown and shiny seeds, Double purpose variety, Oil content 42%.

Variety	National Identity	Pedigree	Developing Institute	Developer	Notification No.	Adaptation Zone*	Yield Q/ha	Specific trait(s)	Additional trait (s)
RLU-6 (Sarswati)	IC5239809	Acc.750/RL-29-8	MPUA&T,Udaipur, Rajasthan	Dr. (Mrs.)Veena Bhatanager	State, 2002	II	17	High yielding, Resistant to rust and Bud fly & resistant to Powdery mildew and Alternaria blight	White flowers, Brown colour seeds, Oil content 40.48%
BS-44	NA	NA	Not Known	Not available	State,1955	II,III	15	Resistant to rust and wilt	White flower, Bold and brown seeds
C-429	NA	H-3/IP-135	Maharashtra	Not available	429 E, 03.01.1983	III	10	Resistant to rust	Moderately spreading type, non dehiscent fruit, brown seeds, Denotified
Co.4 (MS-1316)	NA	NA	Not Known	Not available	State, 1985		10	Non lodging, Tolerant to drought and shoot fly, early maturity	Heavy tillering, Shiny yellow and bold seeds
IPI-6	NA	Sel from local material in Central Province	Not Known	Not available	State, 1964		8	Bold seeds	Blue flowers
Jawahar-1 (JLS-1)	NA	Selection of KP-29	Jawaharlal Nehru Krishi Vishvavidyalaya (JNKVV), Jabalpur, MP	Dr. S.K.Agrawal	19 E, 14.01.1982	III	9	Resistant to rust and wilt	Semi spreading type, Blue, synchronous flowering and maturity, brown seeds
Jawahar-17 (R-17)	NA	Selection of No.55	JNKVV, Jabalpur, MP	Dr. S.K.Agrawal	19 E, 14.01.1982	III	13	Resistant to rust	Erect plant with medium tillering, Brown and bold seeds
Jawahar-7 (R-7)	NA	Selection of No.55	JNKVV, Jabalpur, MP	Dr. S.K.Agrawal	19 E, 14.01.1982	III	7	Resistant to rust, Suitable for *utera* cultivation	Erect plants with deep root system, blue flowers with white ring in centre, Brown and medium seeds
Jeevan (DPL-21)	NA	Summit/LC-216	Ch.S.K.H.P.K.V, Palampur, HP	Dr. H.L.Thakur	10 E, 01.01.1988	I	11	Resistant to rust, wilt and Powdery mildew	Tall plant, Brown seeds, low tillering, uniform maturity, Oil content 45%
Jawahar Linseed-9	NA	RL-102/R-7//J-23	JNKVV, Jabalpur, MP	Dr. S.K.Madaria	425 E, 08.06.1999	III	10	Earliness, Resistant to rust, wilt and Powdery mildew	Medium height, white flowers, medium maturity, suitable for both rain fed and irrigated conditions. Oil content 42%
K-2	NA	Kangra Local/ Nagarkot/ Bhagvan Local	PAU, Ludhiana, Punjab	Not available	44 E, 21.08.1975	I,II	11	Resistant to rust, Powdery mildew & wilt, Frost tolerant	Tall plants with low tillering, white flowers, brown and bold seeds
M-10	NA	NA	Not Known	Not available	State, 1901	III	5	Resistant to rust and wilt	Medium and bold seeds
Mayurbhanj	NA	Local var of Mayurbhanj , Orissa	Not Known	Not available	State, 1978	III	10	Resistant to rust and wilt	Bold seeds with shiny brown colour

Variety	National Identity	Pedigree	Developing Institute	Developer	Notification No.	Adaptation Zone*	Yield Q/ha	Specific trait(s)	Additional trait (s)
No. 55	NA	Developed from local bulk at Nagpur	Not Known	Not available	State, 1985	III	6	Bold seeds	Errect and profusely branched, Medium, dark brown and Bold seeds
NP (RR) 9	NA	Derivative of NP-124 x A 17-1-1	Not Known	Not available	State, 1984	I, II, III	11	Early maturity and good yield	Errect and compact plant, white flowers
Pusa -2 (L.S.2)	NA	Selection BS-12	All India Co-ordinated Research Project on Linseed (AICRP on Linseed), Kanpur, UP	Dr. S.D.Dubey	295 E, 09.04.1985	I,III	13	Resistant to rust and wilt, bud fly, Resistant to drought, Non shattering	Errect and compact plant, Brown and lustrous seeds, Oil content 45%
Pusa -3 (L.S.3)	NA	K-2/T-603	AICRP on Linseed, Kanpur, UP	Dr. S.D.Dubey	295 E, 09.04.1985	I,III	11	Resistant to rust and wilt, bud fly, Resistant to drought, Non shattering	Errect and compact plant, brown seeds, oil content 45%
S-36	NA	Selection from local material	MPKV, All India Coordinated Research Project On Oil Seeds, Jalgaon, Maharashtra	Not available	State, 2004	III	4	Drought resistance, Tolerant to powdery mildew & Alternaria blight	Semi spreading type, Brown seed colour
S-48	NA	Selection from local material	MPKV, All India Coordinated Research Project On Oil Seeds, Jalgaon, Maharashtra	Not available	State, 1959	III	5	Medium size seeds	Tall plant, chocolate colour seeds

NA: The seed is not available in the Gene Bank;

*Zone 1 : Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir;

Zone II: Gangetic alluvium of Uttar Pradesh, Bihar, Jharkhund, West Bengal, Assam;

Zone III: Bundelkhund region of Uttar Pradesh, Madhya Pradesh, Chattisgarh, Orissa, Karnataka, Maharashtra and Rajasthan.

UP = Uttar Pradesh; HP = Himachal Pradesh; MP = Madhya Pradesh

Table 2. Sources of resistance in linseed varieties/ strains

Abiotic/biotic stresses	Sources of resistance
Abiotic stresses/Agronomic traits	
High yielding	Shekhar, Shubhra, Parvati, BS-44, Neelum, RLU-6, Suyog, Sheela, Surabhi, Himalini, NL-142, RL-914
Early maturity	RLC-76, Jawahar-1, NL-142, JLS-9, NL-97, RLC-81, RLC-29, TLP-1
Drought Tolerant	Sweta, Co-4, Pusa-2, Pusa-3, S-36
Frost Tolerant	Sweta, LC-54, J-23, LC-185
Tolerance to salinity/ sodicity	Hira, Mukta, T-397, Sweta
Non shattering types	Sweta, Parvati, Hira, Chambal Alsi, Jawahar-23, C-429, Pusa-2, Pusa-3
Early maturity	Parvati, NL-97,Sheela, Surabhi, RLC-81, RLC-76, NL-142, Himalini, LMS-4-27, Jawahar linseed-9, NP (RR)9
Double purpose	Gaurav, Meera, Jeevan, Nagarkot, Shikha, Rashmi, Parvathi, Neelum, Padmini
Utera Cultivation	LC-185, Jawahar-552, Jawahar-7
Biotic stresses	
Powdery mildew	Shekher (LCK-9313), NL-97, RLC 81, Parvati (LMH-16-5), LC- 54, Surabhi, Sheela, Rashmi, Meera, Shikha, Laxmi 27, Jeevan, Suyog (SLS-27), Nagarkot, LMS-4-27
Rust	RLC–76, JLS-9, Shekar, Swetha, Shubra, Baner, Garima, Padmini, Himalini, Parvati, RLU-6, Binwa, Kiran, LC-54, Surabhi, Sheela, Rashmi, Jeevan, Suyog (SLS-27), Nagarkot, T-397, Guarav
Wilt	JLS-9, Binwa, Kiran, Surabhi, Sheela, Rashmi, Meera, Shikha, Laxmi 27, Jeevan, Suyog, Nagarkot, LMS-4-27, RS- 552, T-397, Guarav
Alternaria blight	Nagarkot, LC-54, NL-97, RLC-76
Bud fly	NL-142, Suyog, LMS-4-27, Neela, NL-97

stresses viz., development of high yielding and early maturity varieties, edible grade oil varieties in linseed. Resistance to insect pests and viruses is an achievable goal in many instances. Search for novel insecticidal proteins and characterization of viruses specific to oilseed crops is an important endeavour. Recent trends indicate that management of bacterial and fungal disease to the desirable extent is also feasible.

These varieties contain important constellations of useful genes, but may need further improvement to meet the requirement of changing scenario. In order to have their effective utilization, inventorisation and conservation of these varieties is essential. The present article is an attempt in this direction. Authors hope that the preliminary information assembled on released varieties of linseed with desired information and their availability in the National Gene bank will facilitate their use in linseed improvement programme of India.

References

Prakash Anand and DP Chaturvedi (1978) Larval parasitization of the gingelly blossom midge *Dasineura sesami*. *Indian J. Pl. Prot.* **6(2):** 83.

Bickert CW Luhs and W Friedt (1994) Variation for fatty acid content and triacylglycerol composition in different *Linum* species. *Industrial Crops and Products* **2**: 229-237.

De Candolle A (1904) Origin of cultivated plants. Kegan Panl. Trends Trulener and Co., Ltd., Hyderabad.

Fan YY and RS Chapkin (1998) Importance of dietary gamma–linolenic acid in human health and nutrition. *J. Nutrition.* **128**: 1411-1414.

Gill KS (1987) Linseed, ICAR Publi. New Delhi, pp.386.

Gill KS (1966) Evolutionary relationships among *Linum* species. Ph.D. Thesis, University of California, Riverside. p. 243.

Green AG (1986) A mutant genotype of flax (*Linum usitatissimum* L.) containing very low levels of linolenic acid in its seed oil. *Canadian J. Plant Science* **66**: 499-503.

Helboek H (1956) Vegetables in funeral meals of pre-urban Rome. In "Gjerstd E: Early Rome". Metomba 2: Append **1**: 287-294.

Mchughen A (1992) Revitalization of an ancient crop. Exciting new developments in flax breeding. *Plant Breeding Abs.* **62**: 1031-1035.

Planchen JE (1848) Sur la familiee des Linees. Hokker's Lond *J. Botany* **6**: 588-603.

Rai. M and TS Sinha (1980) Genetic adaptation to saline soil conditions in linseed. *Annals of Arid zone* **19**: 271-277.

Richharia RH (1962) Linseed. The Indian Central Oilseeds Committee, Hyderabad. p. 155.

Simmods NW (1976) Evolution of crop plants. Longman Inc., New Yark.

Smith CE (1969) From Vavilov to the present–A review. *Economic Botany* **23**: 2-19.

Tiwari SP (2002) In: Rai M, H Singh and DM Hedge (Eds) Biodiversity in oil seed crops. Oil seeds and oils-Research and development needs. pp 68-100.