# Sugarbeet Pre-breeding in India

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## ABSTRACT

**Sugarbeet is primarily a crop of temperate climates, but in the last two decades its culture has spread to sub-tropical climates. Sugarbeet was introduced in India in 1971 as a supplementary sugar crop to augment cane sugar production in the hot summer months. Initially, sugarbeet varieties were introduced from Europe, USSR, and the USA. Work was initiated in 1971 to develop breeding material and varieties suitable to our climatic conditions. Since sugarbeet does not flower in the plains of India due to a lack of proper temperatures, breeding and seed production work is done at elevations above 5,000 feet above sea level. There are four main breeding objectives: higher sugar yield, resistance to diseases, tolerance to high temperature conditions at harvest, and tolerance to saline-alkaline conditions. Achievements outlined include development of basic breeding material, selection of populations that may be used as commercial varieties, development of experimental hybrids, and induction and development of tetraploids. Also described is the screening of materials for tolerance to disease, high temperature, and salinity.**

**Additional Key Words:** *Beta vulgaris,* hybrid, inbreds, composites, synthetics, polyploids, tetraploids, sucrose, CMS, O types, *Sclerotium, Cercospora,* impurity index.

In India more than 3.6 million hectares of sugarcane *(Saccharum officinarum* L.) are grown, with an average yield of 65 tons of cane per hectare and sugar recovery of more than 9.8%. In the 1991-92 season, the 392 sugar factories in India produced 13.4 million tons of white sugar. The country, therefore, is self-sufficient for its sugar requirement and also exports sugar (Anonymous, 1993). Why, then, would sugarbeet *(Beta vulgaris* L.) be wanted in India? Sugarbeet was introduced in India as a supplementary crop because of its short growing season (6 months) compared to sugarcane (12-18 months). Sugarbeet requires less irrigation than sugarcane and has higher sugar recovery. The main drawback, however, is that it requires extra fuel for its processing whereas bagasse is used as fuel in the processing of sugarcane. With our ever-increasing population, additional sugar will be needed by 2000 AD. The area cultivated for sugarcane cannot be increased due to land requirements for cereals and pulses. Therefore, in order to keep balance in agricultural production, we will require more area under short duration crops like sugarbeet. At present we have only one cane-to-beet sugar factory in India, but more such factories are expected to come in Maharashtra, Karnatka and Punjab.

Sugarbeet is primarily a crop of temperate climates. Its commercial cultivation in the last two decades has extended to subtropical countries such as Afghanistan, Egypt, Iraq, India, and Pakistan. Sugarbeet was introduced in India as a supplementary sugar crop to augment sugar production in the hot summer months of April and May when sugar recoveries from sugarcane show a steep decline trend. In northern climates, sugarbeet sowing is generally done in March and April and the root crop is harvested from October onwards when the temperatures are low. In India and other sub-tropical countries, the sowing is done in October-November and the root crop is harvested in the hot summer months of April and May when temperatures range between 35-45°C. We need varieties suitable for such sub-tropical climatic conditions. Therefore, efforts were made to develop our own breeding material and varieties suitable to Indian conditions; the work done in this direction is described in this paper.

## SUGARBEET BREEDING CENTERS AND VARIETAL TESTING

**Breeding Centers.** Sugarbeet breeding and seed production work in India was initiated in 1971 with the advent of the All India Coordinated Research Project on sugarbeet (ICAR). This work was started at two centers located at the Indian Institute of Sugarcane Research, Lucknow and the G. B. Pant University of Agriculture and Technology, Pantnagar. A third center situated at 10,000 feet above sea level was started at Kalpa (H.P.) for seed production research and seed multiplication.

**Evaluation of Exotic Varieties.** Initially, large numbers of diploid and polyploid hybrids and open pollinated varieties were imported from different parts of the world. They were evaluated under a multilocation testing program to assess their suitability and stability under Indian conditions (Srivastava et al., 1974; Tripathi and Srivastava, 1978). Some of these varieties, viz. Maribo Magnapoly, M. Resistapoly, Marocpoly, Mazzanopoly, and Virtus among polyploids, and Ramonskaya-06 among diploids, performed well and have been recommended for commercial cultivation (Anonymous, 1988).

**Need for Indigenous Varieties.** Indigenous varieties are needed for the following reasons:

a) most introduced varieties are susceptible to *Sclerotium* root rot and do not show tolerance to high temperatures at harvest,
b) there is need for independence from foreign varieties, and
c) it is Government policy to save foreign exchange.

## SUGARBEET BREEDING PROGRAM IN INDIA

Because sugarbeet does not flower in the plains of India due to lack of proper thermal induction, breeding and seed production work is done in the hills at elevations of 5,000 feet and above (Kapur et al., 1986; Srivastava et al., 1983, 1986). Stecklings are raised in the plains; after initial selection they are transported to the hills and transplanted to obtain photothermal induction for flowering and seed production.

There are no private seed companies involved in sugarbeet breeding or seed production in India. All the work involved in the development of breeding lines, parental lines, hybrids and synthetics lies with the ICAR institutes or Agricultural Universities. Once the variety or hybrid has been developed and found suitable for commercial cultivation, the foundation seed or the parental lines are passed on to the National Seeds Corporation (NSC) which produces certified seed. The work described in the following pages involves steps both on pre-breeding and varietal development.

**Breeding objectives in India.** The major breeding objectives of sugarbeet breeding in India are:

a) higher sugar yield,
b) resistance/tolerance to important diseases,
c) high temperature tolerance at harvest,
d) tolerance to saline/alkaline conditions.

## BREEDING FOR HIGHER SUGAR YIELDS

**Development of breeding lines.** Breeding for higher sugar yield involves higher root yield, moderate sugar content, and low impurity index. The main constraint in the breeding efforts in India has been the lack of availability of germplasm, breeding lines and open pollinated varieties. Therefore, one of the important aspects of the breeding program has been the collection and maintenance of diploid open pollinated varieties, the study of genetic variability, (Baldev Raj and Bhatnagar, 1979; Srivastava et al., 1989, 1991; Kapur et al., 1985, 1987) and the development of our own inbred and elite lines. As a result of these objectives, inbreeding work was initiated in diploid, multigerm varieties obtained from Europe (Srivastava et al., 1989). Forty diploid, multigerm inbred lines have been produced. One diploid, multigerm, male sterile line along with its O type has also been developed.

**Breeding methods used.** Three breeding methods have been used in India:

a) population improvement through modified mass selection and recurrent selection,
b) heterosis breeding initially employing composite and synthetic breeding programs in the beginning, and with the availability of some male sterile lines (CMS) from USA, (Hecker, pers. comm. 1984; McFarlane, pers. comm., 1987) the production of three way cross hybrids (Srivastava, 1990), and
c) the production of anisoploid hybrids using colchicine induced tetraploid as female and diploids as male.

**Development of diploid varieties, composites and synthetics.** In the first phase of this program, LS-6, a diploid, multigerm, open pollinated variety, was developed through modified mass selection. This genotype proved highly promising in our multi-location testing. It showed tolerance to *Sclerotium rolfsii* root rot and to high temperature conditions, maintaining a low impurity index. Two other promising elite lines, IISR-2 and LS-7, were developed from diploid varieties through mass selection methods at Pantnagar University, and along with LS-6 were recommended for commercial cultivation in India (Anonymous, 1988).

In the second phase of the program, efforts were concentrated on the development of some populations which may be introduced as varieties and may also serve as base material for the future. On the basis of *per se* performance and also on the basis of combining ability (Srivastava et al., 1986; Tripathi and Srivastava, 1978) some composites, namely: IISR Comp-1, LKC-2, Pant Comp-1, Pant Comp-3 and synthetics, LKS-10 were synthesized at Lucknow and Pantnagar. Out of these IISR Comp-1, PC-3 and LKS-10 were identified as highly promising. IISR Comp-1 has been recommended for commercial cultivation in India (Figure 1).

In the third phase of the breeding program, with the availability of some CMS lines and their O types through the courtesy of Dr. R.J. Hecker (USDA-ARS, Fort Collins, Colorado), and Dr. J. McFarlane (USDA-ARS, Salinas, California), work was initiated to develop some experimental hybrids. Two diploid, three way cross hybrids (LK Hy-1 and LK HY-2) were developed (Srivastava, 1990, 1991). These composites, synthetics, and hybrids were evaluated at three locations. Data show that some of them have an increase of more than 20% for root and gross sugar yield (Table 1) compared with the check.


**Figure 1.** IISR Comp-1, an India-developed composite that has been recommended for commercial cultivation in India.

Simultaneously, work was initiated to induce tetraploidy in promising diploid lines (Srivastava, 1984; Srivastava et al., 1985, 1986) and also to isolate diploid and tetraploids from anisoploid varieties (Srivastava and Ethirajan, 1971; Srivastava et al., 1988). As a result, some tetraploids have been isolated and will form the base for future triploid hybrids. One experimental anisoploid hybrid was also developed which showed promise (Table 2).

**Table 1:** Relative performance of diploid sugarbeet hybrids, composites and synthetics compared with check variety Romonskaya (1988-89)[†].

| Composites/ | % of check | | | |
|---|---|---|---|---|
| Synthetics | Root Yield | Top Yield | Sucrose % | Gross Sugar |
| LK Hy-1 | 121 | 133 | 101 | 121 |
| LK Hy-2 | 94 | 102 | 106 | 99 |
| IISR Comp-1 | 117 | 109 | 110 | 129 |
| LKS-10 | 114 | 101 | 108 | 116 |

[†] Pooled data of three locations.

**Table 2.** Root and sugar yields of some polyploid sugarbeet hybrids developed at IISR, Lucknow, India.

| Genotype | Root Yield | Sucrose | Gross Sugar |
|---|---|---|---|
| | t/ha | % | t/ha |
| LK Polyhybrid-1 (MOT x LS-6) | 90.41 | 16.94 | 15.32 |
| LK Polyhybrid-2 (MOT x IISR-2) | 44.58 | 18.25 | 8.13 |
| Ramonskaya-06 (check) | 74.40 | 18.35 | 12.91 |
| General Mean | 67.33 | 17.50 | 11.72 |
| CD at 5% | 33.46 | NS | — |

These results indicate that despite our meager facilities and limited resources, we have been able to develop some varieties with improved adaptability and performance under sub-tropical conditions. However, more intensive efforts and better resources in terms of physical facilities, germplasm and breeding lines are needed to develop better varieties.

## BREEDING FOR DISEASE RESISTANCE

Combining the resistance for major disease prevalent in root and seed crops with high yield and sucrose content is an important objective.

**Major diseases of sugarbeet in India.** Most of the major diseases, i.e. seedling diseases, leaf spots, and root rots occur in India (Singh et al., 1974; Mukhopadhyaya and Upadhyaya, 1986). In the seedling stage, infections caused by *Pythium* sp. and *Rhizoctonia* sp. are important. *Cercospora* is a serious problem in the seed crop and to a lesser extent in the commercial crop (Kaw et al., 1979). *Alternaria* leaf spot is also frequently observed in seed crops. In the root crop, *Sclerotium rolfsii* and *Rhizoctonia solani* have been reported (Singh et al., 1973, 1974; Mukhopadhyaya, 1971). *Sclerotium* root rot is the most prevalent in India and appears with the rise in temperatures in March.

**Screening of varieties/germplasm to identify resistance sources.** Most of the available diploid and polyploid varieties have been screened under artificial epiphytotic conditions at Pantnagar and Lucknow. Screening for resistance to *Cercospora* has been mainly done at Pantnagar, while screening against *Sclerotium* has been done at Lucknow, Pantnagar, and Jalandhar (Mukhopadhyaya and Rao, 1978; Srivastava and Tripathi, 1990; Waraitch, 1985). Through use of visual grading, various levels of tolerance to these diseases have been found. Some varieties have shown good tolerance to *Cercospora* leaf spot (e.g. M.R. Poly, LS-6, IISR-2) and others have been found to be tolerant to *Sclerotium rolfsii* (e.g. M.M.Poly, LS-6, IISR Comp-1, R-06).

Due to the polyphagous nature of the *Sclerotium* fungus, no resistant variety could be developed for this disease. However, in the composite breeding program, varieties that showed tolerance to *Sclerotium* were developed (IISR Comp-1, LK-C2).

## BREEDING FOR HIGH TEMPERATURE TOLERANCE

The sugarbeet crop is harvested in India during the hot summer months of April and May when temperatures range between 35 and 45°C with hot dry winds. These conditions are quite different from those prevalent in temperate climates. Therefore, varieties suitable for our conditions must tolerate high temperatures and have low transpiration rate.

**Criteria for identification of high temperature tolerance.** Late harvesting of the sugarbeet root crop, i.e. from the third week of May onward, results in high mortality of roots and an increase in the impurity index. Therefore, in screening of varieties, three important attributes are taken into consideration:

a) higher survival of roots at the late harvest and high temperature conditions (40-45°C),

b) good root yield, and

c) lower impurity index (Srivastava et al., 1978).

Those varieties that perform well in respect to all three attributes are considered tolerant to high temperatures.

**Screening of sugarbeet varieties for high temperature tolerance.** A large number of diploid and polyploid varieties have been screened at Lucknow, Sriganganagar (Srivastava et al., 1978, 1983, 1991), and Pantnagar (Bhatnagar and Baldev Raj, 1979). Among diploid varieties, Ramonskaya-06, AJ-3, AJ-4, OPH, LS-6, and IISR-2, and among polyploids, M. Magnapoly, M. Marocpoly, and Mezzanpoly have been identified as tolerant to high temperatures at late harvest. At late harvest, impurities, including Na, K, and amino nitrogen also increase. Studies were initiated to evaluate changes in sugar and impurity index at each weekly harvest in May and June (Figure 2). Agrawal and Srivastava (1987) also studied the effects of storage temperatures on post-harvest quality of roots and concluded that harvested roots should be processed in the mill as early as possible, preferably within 24 hours after harvesting. Storage of roots for more that 24 hours tends to increase both the impurities and the difficulty in slicing of roots. There is a need to screen wild sugarbeet germplasm and breeding lines to identify sources of high temperature tolerance for use in future breeding programs.

**Development of genotypes for high temperature tolerance.** Diploid sugarbeet varieties found tolerant to high temperature conditions have been used extensively for the development of composites. Some of the genotypes like Ramonskaya-06 and LS-6 are being used as pollinators in the production of experimental hybrids (Srivastava, 1989,1990).

## BREEDING FOR SALT TOLERANCE

The Indian Council of Agricultural Research (ICAR) opened a center of All India Coordinated Research Project on sugarbeet in 1987 to investigate the potentialities of growing sugarbeet on saline-alkaline lands. A large number of available diploid and polyploid varieties have been evaluated at Banthara, Lucknow (U.P.) (Garg, 1987; Garg and

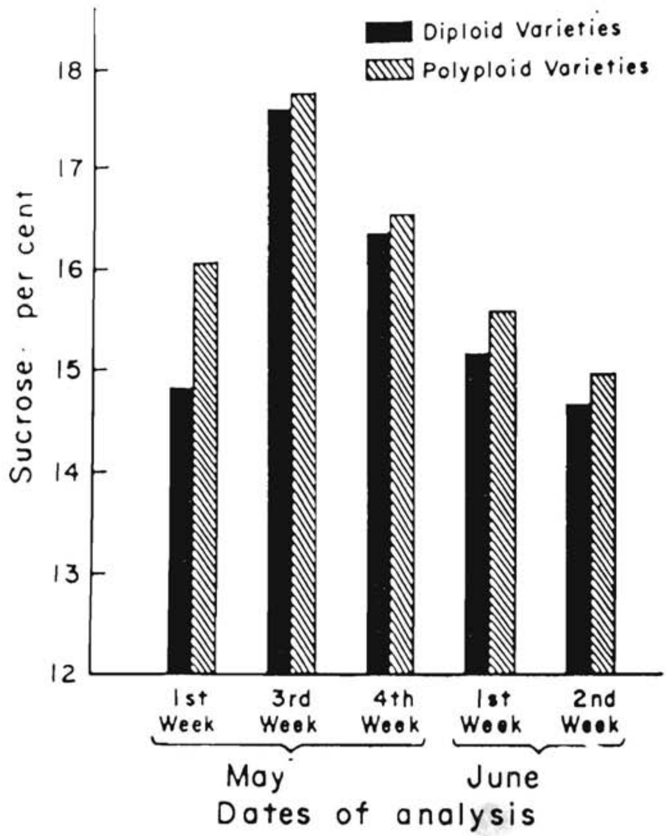


**Figure 2.** Sucrose percent on different dates for sugarbeet varieties screened for heat tolerance.

Khanduja, 1986; Chandra, 1991), Karnal (Haryana) (Bhattacharya, 1983,1986) and Sunderbans/Kalyani by many workers in order to identify sources of salt tolerance. Some varieties (e.g. Ramonskaya, LS-6, IISR Comp-1, CLR PB, II/79, and M.R. Poly) have been identified which grow well under such situations. *B. maritima* is reported to grow well near coastal areas and sea shores. Therefore, it will be appropriate to evaluate different collections of this species under natural saline-alkaline conditions of India. The sugarbeets produced in this area may be used for alcohol production (Anonymous, 1983).

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## LITERATURE CITED

Anonymous. (1983). Indian Sugar. April, 1993.

Anonymous. 1988. All India Co-ordinated Research Project on Sugarbeet (ICAR). General Recommendations, 1988.

Anonymous. 1993. Alcohol fuels options for developing countries, National Academy of Sciences, Washington DC, USA.

Agrawal, M.P. and H.M. Srivastava. 1987. Effect of storage temperature on post harvest quality of sugarbeet. Ind. Jour. Agr. Sci. 57(11):825-828.

Bhatnagar, P.S. and Baldev Raj. 1979. Genotypic variability in sugarbeet with reference to the effect of storage after normal and delayed harvesting. Ind. Jour. Agr. Sci. 49(8):583-591.

Baldev Raj and P.S. Bhatnagar. 1979. Genetic variability and heritability for some traits in sugarbeet, inbred lines. Ind. Jour. Sugarcane Tech. 2(1):49-54.

Bhattacharya, R. K.. 1983. Note on the performance of sugarbeet in highly sodic soils. Curr. Agr. 7(3-4):195-196.

Bhattacharya, R. K.. 1986. Tolerance of sugarbeet varieties under alkali soils. Ind. Agr. 30(4):301-305.

Chandra, V.. 1991. Sugarbeet in sodic soils, possibilities and prospects for its cultivation in India. Paper presented at the Technical group meeting on Sugarbeet held at IISR, Lucknow, Sept. 21-22, 1991, p. 1-14.

Garg, V.K.. 1987. Sodium mining by sugarbeet. Bio. Memori. Vol.13.

Garg, V.K. and S.D. Khanduja. 1986. Energy efficiency ratio of sugarbeet grown on alkali soils in Northern India. Biomass 11:1-5.

Kapur, R., B.L. Srivastava, H.M. Srivastava and V.K. Saxena. 1985. Character association in sugarbeet. Agr. Sci. Digest. 5(1):17-20.

Kapur, R., B.L. Srivastava and H.M. Srivastava. 1986. A new technique for vegetative propagation of sugarbeet seed crop. Ind. Sugar Crops Jour. p. 16-17.

Kapur, R., H.M. Srivastava, B.L. Srivastava and V.K. Saxena. 1987. Genetic diversity in sugarbeet. Ind. Jour. of Genet. 47(1):79-83.

Kaw, R.N., A.N. Mukhopadhyay and A.K. Dullo. 1979. Fungicidal control of *Cercospora* leaf spot of sugarbeet in seed producing area. Ind. Phytopath 32:405-408.

Mukhopadhyay, A.N.. 1971. *Sclerotium* root rot of sugarbeet in India. Mycopath et. Mycol. Applicanta 44:265-270.

Mukhopadhyay, A.N. and S.V.R.K. Rao. 1978. Losses caused by *Cercospora* leaf spot in Pantnagar grown sugarbeet. Ind. Phytopath. 31:229-231.

Mukhopadhyay, A.N. and J.P. Upadhyay. 1986. Diseases of sugarbeet and their control. Rev. Trop. Pl. Path. 3:267-319.

Singh, K., V.P. Agnihotri, S.N. Srivastava and S.R. Misra. 1973. *Rhizoctonia bataticola* (Taub). Butter causing root rot in sugarbeet *(Beta vulgaris* L.). Ind. Jour. Agr. Sci. 43:361-365.

Singh, K., S.N. Srivastava, C. Sen and V.P. Agnihotri. 1974. Problems of sugarbeet pathology in India. A critical appraisal. Ind. Sugar 24:383- 389.

Singh, K., C. Sen and S.N. Srivastava. 1974. Sugarbeet *(Beta vulgaris* L.), Sclerotium rolfsii, fungicide and nematicide tests. Am Phytopath. Soc. 30:102.

Srivastava, H.M.. 1984. Polyploid breeding in sugarbeet. 1. Usefulness of stomatal characters in determining ploidy in sugarbeet. 7th All India Botanical conference, IJBS, Vol 63, p. 86.

Srivastava, H.M.. 1989. Heterosis breeding in sugarbeet. An approach for sugarbeet improvement in India. National Symposium on "Recent Advances in Genetics and Plant Breeding Research in India". B.H.U., Varanasi, Nov. 14-15, 1989. p.4.

Srivastava, H.M.. 1990. Development of diploid and polyploid hybrids of sugarbeet for sub-tropical climate and their seed production potentials. International conference on Seed Science and Technology. New Delhi, Feb. 21-25, 1991. p.8.

Srivastava, H.M.. 1991. Breeding and improvement of sugarbeet for sub-tropical climate. 2nd International Beta Genetic Resources Workshop. FAL, Brauns chweig, Germany, June 24-28, 1991. International Crop Network Series, No.7, IBPGR, p.70-71.

Srivastava, H.M. and A.S. Ethirajan. 1971. A modified leaf squash technique for sugarbeet chromosomes. 2nd workshop of All India Co- ordinated Research Project on sugarbeet, Solan, July, 1971.

Srivastava, H.M., B.K. Tripathi and R.K. Shukla. 1974. Genotype year interaction in sugarbeet. Ind. Sugar. 24(3)191-193.

Srivastava, H.M., B.L. Srivastava and V.K. Saxena. 1978. Screening of sugarbeet varieties for heat tolerance. Ann. Report, IISR, Lucknow.

Srivastava, H.M., B.L. Srivastava and V.K. Saxena. 1983. Sugarbeet seed production in the Kumaon hills. II. Effect of steckling size and time of transplanting on yield of sugarbeet seed. Ind. Sugar Crops Jour. 9:21- 24.

Srivastava, H.M., B.L. Srivastava, M.P. Agrawal and V.K. Saxena. 1983. Adaptation for high temperature tolerance in sugarbeet genotypes. XV International Congress of Genetics, New Delhi. Dec.1983. p.640.

Srivastava, B.L., H.M. Srivastava and A.K. Mathur. 1985. Polyploid breeding in sugarbeet. II. Induced tetraploids. Ind. Bot. Reptr. 4(1):12-15.

Srivastava, H.M., R. Kapur and B.L. Srivastava. 1986. Heterosis, combining ability and gene action in a seven parent diallel in sugarbeet. Ind. Jour. Genet. 46(3):484-489.

Srivastava, H.M., B.L. Srivastava and V.K. Saxena. 1986. Comparison of in- situ and transplanting - methods of seed production of sugarbeet in Kumaon hills. Ind. Jour. Agr. Res. 20(4):177-181.

Srivastava, H.M., S.R. Bhat, B.L. Srivastava and A.K. Mathur. 1988. Polyploid breeding in sugarbeet III. Efficiency of stomatal characters for isolating diploids and tetraploids from anisoploid mixtures. Agr. Sci. Digest 8(2):105-108.

Srivastava, H.M., B.L. Srivastava, R. Kapur and V.K. Saxena. 1989. Inbreeding depression in sugarbeet. Ind. Jour. Gent. 49:109-114.

Srivastava, H.M., B.L. Srivastava, M.P. Agarwal and V.K. Saxena. 1989. Components of recoverable sugar and path analysis in diploid varieties of sugarbeet. Ind. Jour of Genet. 49:106-109.

Srivastava, H.M., V.K. Madan, N. Soni, V.K. Saxena and H. Madhok. 1991. Genetic diversity in relation to biochemical parameters. Symp. Ind. Soc. Genet. and Plant Breeding. New Delhi, Feb. 12-15, 1991.

Srivastava, H.M., Sun Yi-Chu, M.N.Arjmand and T. Masutani. 1991. Beta genetic resources activity in Asia. 2nd International Beta Genetic Resources Workshop. FAL, Braunschweig, Germany. June 24-28,1991. International Crop Network Series 7, IBPGR, pp. 12-33.

Srivastava, S.N. and R.C. Tripathi. 1990. Screening of sugarbeet varieties against *Sclerotium* root rot. Ann. Report. IISR. Lucknow, 1990-91, p. 81.

Tripathi, B.K., and H.M. Srivastava. 1978. Yield and stability of some sugarbeet *(Beta vulgaris* L.) varieties. Ind. Jour. Sugarcane Tech. 2:59- 63.

Waraitch, K.S.. 1985. Reaction of sugarbeet genotypes to *Cercospora* leaf spot and *Sclerotium* root rot. Ind. Phytopath. 38:369-370.