Revitalizing Soybean Research in India : Opportunities and Outlook

K. H. Singh

(Received : December 14, 2023; Revised : January 07, 2023; Accepted : January 15, 2024)

ABSTRACT

Soybeans, the "miracle bean" contributes major proportion as an edible oil and animal feed in the world. World soybean production is rising continuously and new cultivars have played a major role in yield improvement. This yield improvement can be achieved through genetic enhancement, germplasm utilization, management of biotic and abiotic stresses and natural resource management. At present, soybean cultivation in India is restricted MP, Maharashtra and Rajasthan though multilocational trials reveled the prospect of expanding the areas of cultivation in Punjab, Haryana and UP. During the last three years, more than >40 high yielding varieties for different geographical regions had been evolved and released under AICRP on soybean. Soybean being a leguminous crop can be promoted as a better crop for soil fertility maintenance in expense of lesser resource utilization compared to other crops like rice.

Keywords : Soybean, Genetic enhancement, Varieties, Management options

Introduction

Soybeans with a unique combination of ~20% oil and ~40% protein are often called as the "miracle bean". In the world, the crop contributes 25% and 65% to the edible oil and animal feed. India earned Rs 2207 crores through export of soybean oil meal in 2021-22 (https://seaofindia.com/export-of-oil-meals-april-2021/). In spite of its belonging to Leguminosae family its use as human protein source is limited and 94% of the world soybean is crushed for oil and animal feed. Globally, Brazil, USA, Argentina, China and India are the major soybean producers with production of 121.8, 112.5, 48.7, 19.6 and 11.2 million metric tons and productivity of 3275, 3318, 2918, 1986 and 928 Kg/ha (FAOSTAT, 2020). In India soybean growing region is concentrated in 3 states with Madhya Pradesh, Maharashtra and Rajasthan contributing 50.7%, 34.1% and 8.8% to area and 35.8%, 48.1% and 8.5% to production, respectively.

Genetic Enhancement

World soybean production is rising continuously and new cultivars have played a major role in yield improvement. Yield gain has shown positive correlation with the year of release of variety with new variety producing higher yield (de Felipe *et al.*, 2016; Fox *et al.*, 2013; Jin *et al.*, 2010; Morisson *et al.*, 2000, Ramteke *et al.*, 2011, Toledo *et al.*, 1990). Major drivers for yield increase in soybean varieties have been increased number of seeds per area,

Director, ICAR-Indian Institute of Soybean Research, Indore, MP, India. *kharendrasingh@gmail.com

number of seeds per pod, number of pods per area, reduced lodging. In India, selection cycle 1 cultivars (developed by selection in exotic introduced material) registered 4 times higher yield and harvest index than local variety Kalitur (Karmakar and Bhatnagar. 1996). Selection cycle 2 cultivars (developed from hybridization among exotic and local material) had 19 and 16% higher yield and harvest index, respectively over selection cycle 1 cultivars. Assessment of yield gain in Indian varieties for 1969 to 2008 revealed 103% yield improvement (23 Kg/year) @2.6% per year. Soybean has higher (40-45%) protein content than oil (~20%) and protein content is still larger (>50%) after extraction of oil. Use of soybean in food is limited and presence of some anti-nutritional (Kunitz trypsin inhibitor, Kti) and undesirable (lipoxygenase, lox2) beany flavor further restricts its use. Higher shelf life of soybean oil is desirable and high levels of oleic acid confer this property. Soybean varieties free from Kti (NRC 127, MACSNRC 1667), lox 2 free (NRC 132) and both Kti and lox 2 free (NRC 142 & NRC 152) and medium oleic (42%; NRC 147) have been developed. Genes for KTi, lipoxygenase and oleic acid content have been identified and markers have been developed (Kim et al 2006 & 2004; Kitamura and Ujiie, 2004). Thin seed coat, its loose attachment with seed and low lignin content make soybean seed coat very susceptible to mechanical forces and harvesting –threshing and post-harvest operations result in losses in seed germination (Carbonell and Kryzanowski, 1995, Kuchlan *et al.,* 2010a, Kuchlan *et al.,* 2010b and Kuchlan *et al.,* 2018). High amount of lignin (more than 400 mg/100g seed coat) content in Lee, MACS 450, MAUS 47, VL Soya 1 was associated with higher strength of seed coat. Breeding lines with high lignin and grain yield are in co-ordinated varietal trial. To overcome the field weathering and improving seed quality, improve seed treatment techniques like thin layer polymer coating with biocontrol agents like Trichoderma and salicylic acid, potassium phosphate, alpha tocopherol application at pod formation or seed development stage have been recommended.

Germplasm utilization

A vast collection of soybean germplasm, about 170,000 accessions present in the world forms a valuable genetic resource for *per se* yield and trait(s) specific improvement. China possesses the largest collection of germplasm (>23,000 cultivated and 7000 wild accessions; followed by USDA-Agricultural Research (>20,000 accessions; Carter et al., 2004) and Japan (11300 accessions). India has 8025 soybean germplasm accessions in which 50% are exotic. Wild soybean (*G. soja Sieb. &Zucc*) is presumed to be the direct ancestor of soybean and constitutes the primary gene pool for *G. max*. While secondary gene pool is not reported in soybean and 26 wild species constitute the tertiary gene pool. Novel sources of resistance to soybean cyst nematode (Riggs and Schmitt 1998), sap-sucking insects (Zhang *et al.*, 2019), rust (Herman *et al.*, 2020), sclerotinia stem rot and sudden death syndrome (Hartman et al, 2000), salt tolerance (Lenis *et al.*, 2011) have been identified in *G. soja* and wild perennial species. Using annual wild relatives, several genes have been identified as contributing to salt tolerance, including

Ncl2, *GmCHX1*, *GmTIP2* (Zhang *et al.*, 2017c), and *GsGST* (Ji *et al.*, 2010). In India, *Glycine soja* has been utilized for introgressing YMV resistance in *Glycine max* and genomic region has been tagged (Rani *et al.*, 2018).

Management of biotic and abiotic stresses

Soybean suffers from several biotic and abiotic stresses which causes severe yield losses and fluctuations in overall production, as well, over the years. Among biotic stresses, pod blight is common to soybean growing regions while charcoal rot, MYMIV, bacterial pustules and frog eye, leaf spot are prevalent in one or other region. Resistant sources for all of these diseases are available in soybean germplasm collection in India. UPSM 534 and *G. soja* have been used as a source of YMV resistance, inheritance of resistance has been divulged and closely linked SSR markers have been identified (Rani A, 2017 & 2018). Inheritance of pod blight resistance has also been determined (Nataraj *et al.*, 2020). Resistance breeding is being continuously conducted and a number of disease resistant varieties have been developed in India. Drought and water logging are the major abiotic stresses affecting soybean production worldwide. Rainfed nature of the crop makes it more vulnerable to abiotic stresses specially in India where the crop is dependent on the vagaries of monsoon. Drought tolerance has been identified in two of the released varieties NRC 7 and JS 97-52. Drought is a complex trait and 37 QTLs related to transpiration rate, plant height, seed weight, relative root and shoot length have been identified (Ren *et al.*, 2020).

Natural resource management for high productivity

Broad bed furrow technology has been a boon for soybean cultivation as it helps both in drought and excess water condition. An impact assessment of this technology has estimated the yield increase of 7.5% and 22.2% over flatbed sowing in improved and farmer's practices, respectively. To take advantage of initial slow growth of sugarcane (0-3months) in spring season, soybean genotypes have been identified for soybean + sugarcane (2:1) intercropping system and 13-15q/ha soybean seed yield has been achieved. Soybean intercropping with maize, pigeon pea and cotton has been standardized for kharif season. Nitrogen fixing *Bradyrhizobium japonicum*, predominant plant growth promoting rhizobacteria (PGPR) *Pseudomonas* and *Bacillus* and arbuscular mycorrhizal fungi (AMF) have been commercially exploited for increasing soybean productivity. Highly efficient nodulating strains *Bradyrhizobium japonicum* (strain USDA 110), *B. liaoningense* 17c (MTCC 10753) have been identified. Endophytic fungus *Mucor ciecinelloides* and bacterium- *Paenibacillusmacerans* have been identified for the control of diseases (Anthrocnose, charcoal rot) and insects (stem fly). Bt 127SC strain has been identified as effective biocontrol agent against lepidopteran insects of soybean.

Future prospects for increasing soybean production

At present, soybean cultivation in India is restricted to three states; MP, Maharashtra and Rajasthan, however, high seed yield recorded in multilocation yield evaluation trials under AICRP-Soybean are very encouraging to further extend its cultivation in the states of Punjab, Haryana and UP, where area under paddy cultivation may be replaced by high yielding varieties of soybean, possessing 2.5 to 3.0 t/ha average productivity at farmer's field. AICRP-Soybean trials have shown higher productivity levels in Bihar and Orissa also and varieties with short maturity duration may fit well to these states. IISR Indore has established the intercropping of soybean with sugarcane in Karnataka (Belagavi) and Maharashtra (Kolhapur) in spring season. Intensive extension efforts of state government are required for introduction of soybean and its demonstration to farmers. Yield gap of 428 kg/ha between farmer's and improved practices is very high and can be bridged through extension efforts. Development of photo-insensitive varieties, may enhance the area of adaptation. Rains at the time of harvesting result in post-harvest sprouting (PHS) and poor-quality seed and varieties with resistance to PHS are required to be developed. Our priorities are to develop photo-insensitive varieties with varying maturity duration, resistance to post-harvest sprouting (PHS), high oleic acid content in oil and food grade quality so they may fit well according to the existing cropping system of the particular region and for varying consumer preferences. In addition, strong support from industry, state agricultural department, seed production agencies, policy planning to ensure the higher price and procurement are required to achieve the higher productivity and production of soybean in India.

Newly released varieties of Soybean

During last three year, under AICRP on soybean, more than >40 high yielding varieties for different geographical regions have been identified and released (table 2). Food grade varieties with null KTi and lipoxygenases were developed to promote food uses. New varieties with biotic and abiotic stress playing role in insulating climate variability related productivity losses.

Table 1 : List of selected new varieties developed, identified and released under AICRP on Soybean

Year of release	Name of Variety	Potential Yield (kg/ha)	Area of adoption	Salient features of the Variety
2020	SL 979	2335	Punjab, Uttar Pradesh (except Bundelkhand region of UP), Delhi),	Tolerant to YMV
	SL 955	2201	Punjab, Uttar Pradesh (except Bundelkhand region of UP), Delhi),	Tolerant to YMV
	PS 1556	2287	Punjab, Uttar Pradesh (except Bundelkhand region of UP), Delhi),	MS to FLS, resistant to YMV and BP

	DSb 32	1917	Southern Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu	Highly resistant to rust & MR to PB(Ct)
	KDS 753	SZ: 2362 EZ: 2053 NEHZ: 1697	West Bengal, Jharkhand, Chhattisgarh, Orissa, Assam and North Eastern states, Southern Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu	Tolerant to rust
2021	NRC 128	2269 (NPZ) 1871(EZ)	Punjab, Uttar Pradesh (except Bundelkh and region of UP), Delhi), West Bengal, Bihar, Jharkhand, Chhattisgarh, and Orissa,	Resistance to pod blight (ct) and moderately resistance to charcoal rot and MYMIV.
	NRC 130	1515	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	resistant to charcoal rot and AR. Moderately resistant to TLS & Pod Blight (ct)
	NRC 132	2288(SZ) 1652(EZ)	Southern Maharashtra, Karnataka, (except rust prone area) Telangana, Andhra Pradesh and Tamil Nadu, West Bengal, Bihar, Jharkhand, Chhattisgarh, and Orissa.	First variety with less beany flavour (null lipoxygenase 2),

	NRC 136	1700	West Bengal, Bihar, Jharkhand, Chhattisgarh, and Orissa. Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	Highly Resistant to Indian Bud Blight. Moderately Resistant to defoliators. Drought tolerant
	NRCSL 1	1706	West Bengal, Bihar, Jharkhand, Chhattisgarh, and Orissa.	Tolerant to YMV and MS to PB (Ct) MR to defoliators (larva/m)
	NRC 147	2362	West Bengal, Bihar, Jharkhand, Chhattisgarh, Orissa, Southern Maharashtra, Karnataka, Telengana, Andhra Pradesh and Tamil Nadu	The first variety with 42±5 % oleic acid content
	RVSM 2011-35	2200	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	Moderately resistant to PB (ct), YMV and TLS.
2021	NRC 138	1789	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	Moderately resistant to PB (ct), TLS, Resistant to YMV

	NRC 142	CZ: 1999 SZ: 2206	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra Southern Maharashtra, Karnataka, Telengana, Andhra Pradesh and Tamil Nadu	KTI and Lox 2 free variety
	AMS 100-39 (PDKV Amba)	2087	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	MR to Charcoal rot and MLS and MS to RAB and YMV, S to Pb (ct) & TLS, Antibiosis reaction for defoliators,
	MACSNRC 1667	2051	Southern Maharashtra, Karnataka, Telengana, Andhra Pradesh and Tamil Nadu excluding rust prone areas on banks of river Krishna like Southern Maharstara, entire area of Belagavi, Dharwad, Haveri Bidar & Bagalkot districts	KTI free variety, MS to PB, S to Rust, MS to PSS
2022	NRC 157	1650	Madhya Pradesh State	NRC 157 provides a wider sowing window and can be sown up to 15 July

	NRC 150	1757.5	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	NRC150 is free from lipoxygenase-**2**,
	NRC 152	1823	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	NRC 152 is double null entry free from lipoxygenase 2 and Kunitz Trypsin Inhibitor.
	NRC 131	1451	Madhya Pradesh State	In soybean the height of the lowest pod for mechanical harvesting should be more than 12 cm and IS 131 conforms to this requirement.
	JS 21-72	2132.4	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	It is categorized as multiple resistant for biotic stresses like yellow mosaic virus, charcoal rot, bacterial pustules, leaf spots.
	HIMSO 1689	2077	Madhya Pradesh, Bundelkhand region of UP, Rajasthan, Gujarat, Marathwada & Vidarbha region of Maharashtra	It has shown low to moderate resistance against girdle beetle in Central Zone

Management of biotic and abiotic stresses

Soybean suffers from several biotic and abiotic stresses which causes severe yield losses and fluctuations in overall production, as well, over the years. Among biotic stresses, pod blight is common to soybean growing regions while charcoal rot, MYMIV, bacterial pustules and frog eye, leaf spot are prevalent in one or another region. Resistant sources for all of these diseases are available in soybean germplasm collection in India. UPSM 534 and *G. soja* have been used as a source of YMV resistance, inheritance of resistance has been divulged and closely linked SSR markers have been identified (Rani A, 2017 & 2018). Inheritance of pod blight resistance has also been determined (Nataraj *et al.*, 2020). Resistance breeding is being continuously conducted and a number of disease resistant varieties have been developed in India. Drought and water logging are the major abiotic stresses affecting soybean production worldwide. Rainfed nature of the crop makes it more vulnerable to abiotic stresses specially in India where the crop is dependent on the vagaries of monsoon. Drought tolerance has been identified in two of the released varieties NRC 7 and JS 97-52. Drought is a complex trait and 37 QTLs related to transpiration rate, plant height, seed weight, relative root and shoot length have been identified (Ren *et al.*, 2020).

Technology for Integrated disease and pest management in soybean

- Seed treatment with thiophanate methyl 450g/l + pyraclostrobin 50g/l w/v FS@2 ml/kg of seed or *Trichoderamavridae* @5 g/kg of seed along with thiamethoxam 30FS @ 10 g/kg of seed for management of soybean diseases and insect pest
- Foliar application of Fluxapyroxad 167 g/l + Pyraclostrobin 333 g/l SC @ 300 ml/ha or Pyraclostrobin 133g/l + Epoxiconaxole 50g/l SE @ 750 g/ha or Pyraclostrobin 20% WG @ 500 g/ha or Trichoderamavridae@ 2.5 kg/ha for management of soybean diseases
- Foliar application of Chlorantraniliprole/ Flubendiamide@ 150 ml/ha or B. thuriangensis/N. rileyi/*B. bassiana* @ 1kg/ha or for management of defoliators, Thiachloprid @ 750 ml/ha for girdle beetle and Indoxacard @ 333 ml/ha for pod borer
- Pheromone traps @ 80-100/ha for Spodoptera and Helicoverpa
- NCIPM Light trap @ 1/ha for insect pest
- Yellow sticky trap @ 200/ha for white fly and aphid.
- Use of trap crop suva for management of defoliator sand dencha for girdle beetle

Natural resource management for high productivity

Broad bed furrow technology has been a boon for soybean cultivation as it helps both in drought and excess water condition. An impact assessment of this technology has estimated the yield increase of 7.5% and 22.2% over flatbed sowing in improved and farmer's practices, respectively. To take advantage of initial slow growth of sugarcane (0-3months) in spring season, soybean genotypes have been identified for soybean + sugarcane (2:1) intercropping system and 13-15q/ha soybean seed yield has been achieved. Soybean intercropping with maize, pigeon pea and cotton has been standardized for kharif season. Nitrogen fixing *Bradyrhizobium japonicum*, predominant plant growth promoting rhizobacteria (PGPR) *Pseudomonas* and *Bacillus* and arbuscular mycorrhizal fungi (AMF) have been commercially exploited for increasing soybean productivity. Highly efficient nodulating strains *Bradyrhizobium japonicum* (strain USDA 110), *B. liaoningense* 17c (MTCC 10753) have been identified. Endophytic fungus *Mucor ciecinelloides*and bacterium-*Paenibacillusmacerans* have been identified for the control of diseases (Anthrocnose, charcoal rot) and insects (stem fly). Bt 127SC strain has been identified as effective biocontrol agent against lepidopteran insects of soybean.

Seed production : Supply of quality seeds of newly released superior yielding varieties of soybean will increase its productivity. The ICAR-IISR and centres of AICRP on soybean are producing breeder seeds as per indent of DAC. The seeds are also produced under seed hub project on oilseeds under NFSM. Participatory seed production by progressive soybean farmers are also helping in providing quality seeds to farmers. Under a unique project 3S1Y, supported by DAC, a large quantity of soybean seeds of recently released varieties have been produced and provided to farmers.

Soybean cultivation in changing climatic conditions

Due to climate change the rainfall pattern and temperature is highly unpredictable. The variation in quantity and duration of rain adversely affect major kharif crop like, rice. Further, the rice cultivation requires high investment in irrigation and fertilizers. On the other hand, soybean requires less amount of water and being leguminous in nature the nitrogen requirement is very less. Moreover, it increases the fertility of soils for next crop. Thus, soybean can be promoted in some northern states like, Punjab, Haryana, Uttar Pradesh and Bihar to replace rice to promote crop diversification. This will also provide an excellent opportunity to increase protein supplementation in diet of these areas.

References

Carbonell, S.A.M. and Krzyzanowski, F.C. 1995. The pendulum test for screening soybean genotypes for seeds resistant to mechanical damage. *Seed Science and Technology* **23**: 331-339.

Carter, T.E., Jr., Nelson, R.L., Sneller, C.H. and Cui, Z. 2004. Genetic Diversity in Soybean. (in) *Soybeans: Improvement, Production, and Uses* (Shibles, R.M., Harper, J.E., Wilson, R.F. and Shoemaker, R.C. eds). https://doi.org/10.2134/agronmonogr16.3ed.c8

de Felipe, M., Gerde, J. A. and Rotundo, J. L. 2016. Soybean genetic gain in maturity groups III to V in Argentina from 1980 to 2015. *Crop Science* **56**: 3066–3077.

Dong, Y.S., Zhao, L.M., Liu, B., Wang, Z.W., Jin, Z.Q. and Sun, H. 2004.The genetic diversity of cultivated soybean grown in China. *Theoretical and Appllied Genetics* **108** : 931–936.

Fox, C. M. *et al.* 2013. Estimating soybean genetic gain for yield in the northern

United States—Infuence of cropping history. *Crop Science* **53**: 2473–2482.

Hartman, G. L., Gardner, M. E., Hymowitz, T., and Naidoo, G. C. 2000. Evaluation of perennial Glycine species for resistance to soybean fungal pathogens that cause Sclerotinia stem rot and sudden death syndrome. *Crop Science* ***40***(2): 545-549

Herman, T. K., Han, J., Singh, R. J., Domier, L. L. and Hartman, G. L. 2020. Evaluation of wild perennial Glycine species for resistance to soybean cyst nematode and soybean rust. *Plant Breeding* **139**(5): 923-931.

Ji, W., Zhu, Y., Li, Y., Yang, L., Zhao, X., Cai, H. and Bai, X. 2010. Over-expression of a glutathione S-transferase gene, GsGST, from wild soybean (Glycine soja) enhances drought and salt tolerance in transgenic tobacco. *Biotechnology letters* **32**(8): 1173-1179.

Jin, J. *et al*. 2010. Agronomic and physiological contributions to the yield improvement of soybean cultivars released from 1950 to 2006 in Northeast China. *Field Crop Research* **115**:116–123.

Karmakar, P.G. and Bhatnagar, P.S. 1996. Genetic improvement of soybean varieties released in India from 1969 to 1993. *Euphytica* **90**:95–103

Kuchlan, M.K., Kuchlan, P., Onkar, M., Ramesh, A. and Husain, S.M. 2018. Influence of seed coat compactness around cotyledons, protein and mineral composition on mechanical strength of soybean [Glycine max (L.) Merrill] seed coat. *Legume Research* **41**(2) : 246-252

Kim, M.S., Park, M.J., Jeong, W.H., Nam, K.C. and Chung, J.I. 2006. SSR marker tightly linked to the Ti locus in soybean. Euphytica 152, 361-366 *Euphytica* **152**(3): 361–366.

Kim, M.Y., Keun, H.A., Hwan, J.T., Young, H.E., Van, K., Kuk, Y.I. and Lee, S.H. 2004. Single nucleotide polymorphism discovery and linkage mapping of lipoxygenase-2 gene (Lx2) in soybean. *Euphytica* **135**:169–177.

Kitamura, K. and Ujiie, A. 2004 Recent progress in soybean breeding for processing and utilization in Japan. (in) *Proceedings of International Soybean Processing and Utilization Conference* (Moscardi, F., Hsangoffmann-Campo, C.B., Saraiva, O.F., Galerani, P.R.,Krzyzanowski, F.C. and Carrão-Panizzi, M.C. eds). Foz do Iguassu, Brazil, pp. 808–814

Kuchlan, P., Husain, S.M. and Chauhan, G.S. 2010a. Evaluation of soybean (Glycine max) genotypes for seed longevity. *Indian Journal of Agricultural Sciences* **80**(2): 141-145.

Kuchlan, M.K., Dadlani, M. and Samuel, D.V.K. 2010b. Seed Coat Properties and Longevity of Soybean Seeds. *Journal of New Seeds* **11**(3): 239-249.

Lenis, J. M., Ellersieck, M., Blevins, D. G., Sleper, D. A., Nguyen, H. T., Dunn, D. and Shannon, J. G. 2011. Differences in ion accumulation and salt tolerance among Glycine accessions. *Journal of Agronomy and Crop Science* **197**(4):302-310.

Morrison, M. J., Voldeng, H. D. and Cober, E. R. 2000. Agronomic changes from 58 years of genetic improvement of short-season soybean cultivars in Canada. *Agronomy Journal* **92**: 780–784.

Nataraj, V., Maranna, S., Kumawat, G., Gupta, S., Rajput, L. S., Kumar, S. and Bhatia, V. S. 2020. Genetic inheritance and identification of germplasm sources for anthracnose resistance in soybean [Glycine max (L.) Merr.]. *Genetic Resources and Crop Evolution* **67**(6): 1449-1456.

Rani, A., Kumar, V., BS, G., Rathi, P., Shukla, S., & RK, S. 2017. Linkage mapping of Mungbean yellow mosaic India virus (MYMIV) resistance gene in soybean. *Breeding science* 67(2): 95-100.

Rani, A., Kumar, V., Gill, B. S., Shukla, S., Rathi, P., & Singh, R. K. 2018. Mapping of duplicate dominant genes for Mungbean yellow mosaic India virus resistance in Glycine soja. *Crop Science* 58(4): 1566-1574.

Ren, H., Han, J., Wang, X., Zhang, B., Yu, L., Gao, H., ... & Qiu, L. J. 2020. QTL mapping of drought tolerance traits in soybean with SLAF sequencing. *The Crop Journal* **8**(6): 977-989.

Riggs, R. D., and D. P. Schmitt. 1988. Complete characterization of the race scheme for Heteroderaglycines. *Journal of Nematology* **20**:392-395

Zhang, H., Yasmin, F., & Song, B. H. 2019. Neglected treasures in the wild—legume wild relatives in food security and human health. *Current opinion in plant biology* **49**: 17-26.

Zhang, D. Y., Kumar, M., Xu, L., Wan, Q., Huang, Y. H., Xu, Z. L., ... andShao, H. B. 2017. Genome-wide identification of Major Intrinsic Proteins in Glycine soja and characterization of GmTIP2; 1 function under salt and water stress. *Scientific Reports* **7**(1): 1-12.