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Genetic improvement of mungbean and urdbean and their role in enhancing pulse production in India

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Abstract

The initial varietal development in *mungbean* and urdbean focused mainly on selection from landraces or the germplasm samples collected, purified and evaluated. However, systematic efforts were made by National Agricultural Research System comprising Indian Council of Agricultural Research and State Agricultural Universities through All India Coordinated Pulses Improvement Project for varietal improvement. National Bureau of Plant Genetic Resources and AICPIP centres collected over 8,000 *Vigna* genetic resources and also introduced germplasm from other countries and made them available for evaluation. Several resistant donors were identified and used to transfer gene(s) for biotic stresses. As a result, a number of high yielding varieties were developed through intraspecific hybridization. Large numbers of these varieties are resistant to one or more major diseases of the specific agro-eclogical niches. Six varieties in mungbean and two in urdbean were also developed through inter-specific hybridization which had new plant type and resistance to prevalent diseases. However, limited success has been achieved for the development of varieties with resistance to insect-pests and abiotic stresses. There is a need to intensify research in these areas through introgression of desirable alleles from secondary and tertiary gene pool into the cultivated type for yield, photo period and temperature insensivity and insect pest tolerance. The onset of genomics provides massive amount of information, but the success will depend on precise phenotyping to achieve desired restructuring in existing plant type.

Key words: Mungbean, urdbean, *Vigna* spp., genetic resources, biotic and abiotic stresses, inter-specific hybridization, pre-breeding

Introduction

In India, more than a dozen pulse crops are grown, which are integral part of cropping systems and are of great significance in sustaining largely cereal based agriculture. They are grown as pure- as well as mixed crop with cereals and oilseeds. Among the pulses, mungbean or green gram (*Vigna radiata* (L.) Wilczek) and urdbean or black gram (*V. mungo* (L.) Hepper) have a unique position in cropping system owing to their shorter life cycle, high per day productivity and diversified uses. Both these crops are cultivated since prehistoric period in India. These crops have wider adaptability and low input requirements with an ability to fix the atmospheric nitrogen in symbiotic association with *Rhizobia* bacteria. The food values of mungbean and urdbean lie in their high and easily digestible protein. The seeds contain 25-28% protein, 1.0-1.5% oil, 3.5-4.5% fiber, 4.5-5.5% ash and 62-65% carbohydrates on dry weight basis. Amino acid analysis indicates that as with most grain legume crops, the concentration of sulphur containing amino acids methionine and cysteine are small. Methionine concentration is larger in urdbean than in mungbean. Lysine values are comparatively large, that is why the protein of mungbean and urdbean is an excellent complement to rice in terms of balanced human nutrition.

The concerted efforts of the *Vigna* breeders over the years have led to development of a number of improved varieties for the different agro-climatic zones of the country. Development of disease resistant, short duration and photo-thermo insensitive varieties of these crops during the last three decades has further helped in expanding the area of these crops to newer niches and cropping systems. A recent approach of breeders towards introgression of useful genes from

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wild background into the cultivated one through distant hybridization is further expected to develop more promising materials in the years to come

Origin

Mungbean and urdbean are the most important species of genus *Vigna*. Occurrence of archaeological records of mungbean and urdbean from anywhere outside India are not known (Kajale 1974). Charred grains of mungbean and blackgram have been reported from Chalcolithic Navdatoli (1500 to 1000 BC). The carbonized grains of wild types of mungbean and urdbean were reported by Kajale (1977) from Daimabad – a chalcolithic site in Ahmednagar district of Western Maharashtra, the site tentatively dated as Circa 2200 to 1000 BC. However, mention of mungbean and urdbean in Vedic text such as Kautilya's "Arthasashtra" and in Charak Samhita point to their origin further beyond the pre-Christian era (Jain and Mehra, 1980). According to de Candolle (1884), Vavilov (1926) and Zukovskij (1962) both of these species have originated in the Indian subcontinent. India has a wide range of genetic diversity of cultivated as well as wild types of both mungbean and urdbean. The wild progenitors of these species are seen in abundance as weeds in waste land areas in different parts of India (Singh et al. 1974 and Chandel et al. 1984). It is believed that mungbean (*Vigna radiata*) and urdbean (*V. mungo*) have been domesticated from *V. radiata* var. *sublobata* and *V. mungo* var. *sylvestris,* respectively. The cultigens and the wild progenitors have 2n=22 chromosomes. The closeness between mungbean and urdbean is so prominent that they have been considered to be variants of a single species. However, both have their respective characteristics, clearly different in morphology (stipule shape, pod and hilum shape, cotyledon colour, pod setting and number of grains per pod) and in chemical composition as well. The difference between mungbean and urdbean, mungbean and its wild progenitor, *V. radiata* var. *sublobata*, and urdbean and its wild progenitor, *V. mungo* var. *sylvestris*, are described by Singh (1982). The cross-ability relationship of *V. radiata-mungo* and their wild and weedy relatives has been presented in detail by Singh (2014).

Collection of germplasm and evaluation

In India, the work on collection of germplasm of pulses was taken up in the beginning of 20th century by Botanical Section of the Imperial Agricultural Research Institute at Pusa, Bihar. The germplasm lines of various types in different pulses were collected and purified. This work continued for several years and resulted in the selection of superior genotypes in different crops. However, systematic efforts were made after the establishment of the All India Coordinated Pulses Improvement Project (AICPIP) with its headquarter at IARI, New Delhi in 1966-67. Later on it was shifted to Kanpur in 1983. In 1970s, National Bureau of Plant Genetic Resources (NBPGR) along with State Agricultural Universities (SAUs) collected germplasm of various pulse crops. Prior to this, the germplasm explorations were taken up by IARI with the support of PL480 project. Some collections were also held at different AICPIP centres of SAUs in the country. Indian Institute of Pulses Research (IIPR), Kanpur has been identified as National site for maintenance of active/ working collection of pulses. The current status of germplasm resources available at national and global level in *Vigna* species are given in Table 1.

Table 1. Current status of germplasm resources (wild and related species) at global and national level

Crop	Global holdings	National holdings at NBPGR		
		Indigenous	Exotic	Total
Mungbean	24,918	3,567	537	4,104
Urdbean	3,767	3,127 + (13)	6	3,146
Wild Vigna	-	490	-	490

Modified from Singh and Singh (2016).
Note: Figures in parenthesis are number of accessions of wild species/relatives of indigenous germplasm

Besides cultivated forms, NBPGR also made efforts to collect wild species of *Vigna* from various parts of the country. In *Vigna*, the recent crop specific explorations conducted during 2006-12 have resulted in collection of *V. aconitifolia* (weedy form), *V. dalzelliana*, *V. khandalensis*, *V. minima*, *V. mungo* var. *sylvestris*, *V. radiata* var. *sublobata*, and *V. vexillata* from Western Ghats of Maharashtra and in Rajasthan. Dana (1998) also collected wild *Vigna* species, namely, *V. aconitifolia* var. *sylvestris, V. dalzelliana, V. hainiana, V. khandalensis, V. mungo* var. *sylvestris, V. radiata* var. *setulosa, V. radiata* var. *sublobata, V. trilobata* from Gujarat, Rajasthan, Maharashtra, Madhya Pradesh, Bihar, Orissa and West Bengal states during 1974-1994.

Biotic and abiotic stresses

An array of diseases (powdery mildew, leaf spots, blights, rusts, mosaics caused by fungi, bacteria, viruses and nematodes adversely affect the yield of mungbean and urdbean (Singh 1981). Diseases like yellow mosaic in mungbean and black gram are damaging these crops throughout the country. Similarly storage grain pests such as bruchids cause damage to the grains during storage. These crops also suffer from a number of abiotic stresses (Table 2). Mungbean and urdbean are sensitive to temperature stress especially at full bloom stage and exposure to high temperature and moisture stresses are responsible to heavy yield reductions. Low temperature is detrimental for germination of both these crops in *spring* season in north India and *rabi* season in parts of Odisha where heat and drought stresses cause adverse effect at reproductive stage. High sensitivity to photoperiod and temperature is another major bottleneck in realizing the yield potential and predicting desired harvest index in these crops.

Table 2. Important biotic and abiotic stresses in mungbean and urdbean

Crop	Season(s)/niche	Stress
Biotic stresses		
Mungbean	*Kharif*	Mungbean yellow mosaic virus (MYMV), Cercospora leaf spot (CLS), web blight, defoliators, sucking insect-pests.
	Zaid (spring/summer)	MYMV, root and stem rot
	Rabi	Powdery mildew, rust, CLS
Black gram	*Kharif*	MYMV, anthracnose, web blight, leaf crinkle virus, sucking insect-pests and defoliators
	Zaid (spring/summer)	MYMV, root and stem rot, stem agromyza
	Rabi/rice fallow	PM, rust, Corynespora leaf spot
Abiotic stresses		
Mungbean	*Kharif*	Pre-harvest sprouting, terminal drought
	Zaid (spring/summer)	Pre-harvest sprouting, heat stress and drought stress, sensitivity to photoperiod and temperature
	Rabi	Terminal drought
Black gram	*Kharif*	Terminal drought, sensitivity to photoperiod and temperature, pre-harvest sprouting
	Zaid (spring/summer)	Temperature stress, drought stress
	Rice fallows	Terminal drought

Source : modified from Singh and Singh (2016)

The development of mungbean genotypes with drought and salinity tolerance, which can retain large number of flowers with productive pods at high temperatures (>40^{o}C), are prerequisite to increase mungbean production in India (Singh and Singh 2011). Under ICAR sponsored programme on National Initiative on Climate Resilient Agriculture (NICRA), a large number of genotypes of these crops have been identified based upon multi-location trials and controlled environments showing tolerance to drought, heat, water-logging, frost and insensitive to photoperiod and temperature. A number of thermo-tolerant and photo-insensitive genotypes have been identified in blackgram including PGRU 95016, IPU 99-89, IPU 94-1, IPU 99-79, BGP 247, Pant Urd 31 and thermo-tolerant genotypes in greengram including IPM 02-3, IPM 02-10 and Pant M -5.

Selection of useful genes from the germplasm

Selection from indigenous and exotic germplasm as well as landraces has played an important role in the development of superior cultivars of pulse crops. Before 1950 virtually all the varieties were developed by selection of superior genotypes from the samples of local cultivars. Some of the varieties were also developed from the exotic materials. From the indigenous cultivars as well as from the exotic cultivars the desirable plants were selected and after their progeny testing the superior pure lines were established. The pure lines were evaluated for yield, yield traits and for reaction to diseases and the best pureline was released for cultivation. This practice continued even after the establishment of AICPIP in 1966-67.

Resistance Breeding for disease and insect resistance

Resistance to major biotic stresses including diseases and insect-pests is one of the major objectives in mungbean and urdbean breeding. Tremendous amount of yield loss is encountered due to these stresses every year in mungbean. Therefore much emphasis has been laid over identification of resistance sources followed by their introgression into cultivated backgrounds. Sources of resistance to various diseases have been identified and used for transferring genes for resistance to important diseases. Resistance to Mungbean Yellow Mosaic Virus (MYMV) is an important component and more than 50 MYMV resistant varieties have been released till date. In addition, some of the commercially released varieties have been found resistant to powdery mildew, *Macrophomina* blight and Leaf crinckle virus (Kaur et al. 2008). AVRDC accession V 4281, V 2396 and V 3495 were resistant to agromyzids whereas, accessions, V 2709 and V 2802 were resistant to bruchids. Resistance to MYMV and bruchids were introgressed through wide crosses, *V. radiata* x *V. radiata* var. *sublobata.* Useful disease resistant genes were also identified from amphidiploids of mungbean x ricebean crosses (Dar et al*.* 1991). Mutagenic treatment has also been used for generating variability for resistance against a number of diseases, i.e., CLS and MYMV and it has led to the development of several high-yielding and MYMV resistant lines which were released in India and Pakistan. In few studies, the resistance in mungbean to Leaf Crinkle virus (LCV) have also been found (Bashir et al*.* 2005). Bruchid (*Callosobruchus maculatus* Fab. and *C. chinensis* L.) is the most important insect causing both field and storage infestation and resulting in huge losses if proper chemical treatment is not done. Resistance to bruchid has been reported in wild types of mungbean (Fujii et al*.* 1989) and black gram (Kashiwaba et al*.* 2003), and among *V. nepalensis* and *V. umbellata* genotypes (Tomooka et al*.* 2000; Vaughan et al*.* 2004). Bruchid resistance gene has been mapped using molecular markers in different mapping populations (Young et al*.* 1992; Kaga and Ishimoto 1998; Miyagi et al*.* 2004; Chen et al*.* 2007).

Genetic studies

A large number of studies have been conducted to understand the genetics of quantitative and qualitative traits in mungbean besides studying inheritance of resistance to various biotic and abiotic stresses (Table 3). The available information pertaining to the inheritance of various morphological characters of these crops cultivated in India has been compiled by Singh (2014). In case of mungbean, the first cross was made in 1932 at Pusa to study inheritance of colour of ripe pods and seed coat surface in mungbean by Bose (1939). He reported that colour of unripe pod is due to the same gene responsible for flower colour. Since then attempts were made to compile the inheritance of morphological traits including plant type , plant colour, leaf type, flower colour, inflorescence type, pod pubescence, pod shape, pod colour, shattering habit, seed coat colour, seed coat surface, hard-seededness in these crops (Singh 1982; Singh 2014). In general, these characters were governed by a single gene except seed colour which was conditioned by two independent genes. Linkage of seed coat colour and pod colour was established in both the crops.

Kumar et al*.* (2006) have thoroughly discussed the inheritance pattern of various economically important traits in this crop. For twining habit, a single dominant gene (*T*) has been reported to be responsible (Khattak et al*.* 1999). However, Pathak and Singh (1963) reported a single recessive gene for this trait. Similarly, semi-spreading habit was reported to be dominant over erect habit and it was reported to be probably governed by a single dominant gene (Pathak and Singh 1963). For indeterminate growth habit, a single dominant gene which inherited independently from leaf shape was reported to be responsible (Talukdar and Talukdar 2003). Among leaf traits, for pentafoliate leaf there are reports of one gene (Chhabra, 1990). There are several reports which suggest that the trifoliate leaf is dominant over the entire leaf and this trait is governed by a single dominant gene (Singh 1980; Chhabra 1990; Talukdar and Talukdar 2003). However, there are also reports of two dominant genes, '*Tlb1*' and *'Tlb2'* with duplicate gene action for trilobed leaves (Sareen 1985). Narrow lanceolate leaf is reported to be controlled by two recessive genes, *'nl1'* and *'nl2'* (Dwivedi and Singh 1985). Mukherjee and Pradhan (2002) indicated that anthocyanin pigmentation in the hypocotyls is controlled by two supplementary genes (*'Sh'* and *'Ph'*) with recessive epistatic interaction. Purple hypocotyls are dominant over purple spotted and green hypocotyls, and purple spotted over green hypocotyls. The purple pigmentation on stem, petiole and veins of the leaves is reported to be conditioned by a single dominant gene '*Ppp1'* with pleiotropic effect (Dwivei

Table 3. Inheritance and gene action of economically important traits in mungbean

Trait	Inheritance	Reference
Plant type and growth habit	Single dominant/recessive gene, semi-spreading is dominant over erect habit	Sen and Ghosh 1959; Pathak and Singh 1963; Khattak et al. 1999
Pubescence	Single dominant gene	Murty and Patel 1973; Sen and Ghosh 1959
Nodulation	Additive and non-additive gene action	Singh et al. 1985
Pigmentation	Single dominant/recessive gene, anthocyanin in hycotyl governed by two supplementary genes	Pathak and Singh 1963; Mishra et al. 1970; Mukherjee and Pradhan 2002
Leaf traits	Single dominant gene, large leaflet is dominant over small leaflet; lobbed is dominant over entire type	Singh and Singh 1995; Singh and Mehta 1953; Talukdar and Talukdar 2003
Stem fasciation	Single recessive gene	Dwivedi and Singh 1990
Inflorescence type	Simple types controlled by two dominant genes and compound types are double recessive homozygous; number of clusters controlled by single gene	Sen and Ghosh 1959; Singh and Singh 1970
Flower color	Single dominant gene	Bose, 1939
Yield components	Additive and non-additive gene action	Singh and Singh 1972; Yohe and Poehlman 1975; Dasgupta et al. 1998; Khattak 2002
Pod color	Single dominant gene	Bose 1939; Sen and Ghosh 1959; Murty and Patel 1973
Pod shattering	Single dominant gene	Verma and Krishi 1969
Seed coat color	One or few genes; mottling governed by single gene	Khattak 1999; Chen and Liu 2001; Lambrides et al. 2004
Seed coat surface	Two complementary genes	Bose 1939; Sen and Ghosh 1959; Murty and Patel 1973
Cotyledon color	Single recessive gene controls green color	Thakare et al. 1960
Hard seeded-ness	One or few dominant genes involved	Lambrides 1996; Singh 1983; Humphry et al. 2005
Pre-harvest sprouting	Additive and non-additive gene action; high G x E interaction	Durga and Kumar 1997
Crop duration	Additive, non-additive and epistatic gene action	Khattak et al. 2001
Seed weight	Small is dominant over larger size	Sen and Murty 1960; Fatokun et al. 1992; Humphry 2005
Protein content	Additive and non-additive gene action	Chandra and Tickoo 1998

and Singh 1986). Similarly, stem fascination is controlled by a single recessive gene (*'fs1'*) having a pleiotropic effect on the number of floral organs. The pubescence of pods is reported to be dominant over non-pubescence and is governed by independent duplicate genes (Khadilkar 1963). In mungbean, a variety of seed coat colors ranging from green, yellow, brown, tan, black, and with mosaics of green, black and yellow are found. Khattak et al. (1999) reported monogenic inheritance for seed coat color. Black, black-spotted and dull-green seed coat colors were found to be dominant over green, non-spotted and shiny green color, respectively. Chen and Liu (2001) suggested that the inheritance of black and green seed colors was controlled by a single gene (*B*), black being dominant over green. More recently, Humphry et al. (2005) reported four loci to be responsible for hard seededness through QTL analysis among which two QTL of hard seededness are co-localized with the loci conditioning seed weight.

The inheritance of resistance to important pathogens in mungbean and urdbean has also been studied. The inheritance studies were conducted on viral diseases like MYMV in blackgram and mungbeen and on bacterial pustule in mungbean. Resistance to MYMV in *Vigna* species is reported to be governed by two recessive genes, however, in few cases resistance has also been reported due to a single dominant/ recessive gene. The bacterial pustule in mungbean is due to a dominant gene. The discordance in the nature of inheritance could be ascribed to racial differences in these studies. The allelic relationships have been studied in case of MYMV only.

Resistant lines of mungbean, Tarai local, L 80, LM 214 and LM 294-1 had non-allelic genes for resistance to MYMV (Shukla and Pandya 1985). The resistance donors to MYMV in black gram (Pant U 84 and UPU 2) had the same gene(s) for resistance (Verma and Singh 1986). P 7, P 27, P 103 and P 115 carried a single dominant non-allelic resistance gene to leaf spot (*C. truncatum*), (Kaushal and Singh 1988). It will be desirable to conduct more studies on the allelic relationships of resistant genes in pulse crops. Several insect-pests cause severe damage to pulse crops, however, less attention is given to investigate the mode of inheritance of resistance to the insect pests (Table 5). The bruchids (*Callosobruchus chinensis*) damage the stored pulses. Resistance to bruchids in mungbean is dominant and is governed by few major genes (probably two) with some modifiers (Sarkar and Bhattacharya 2014).

Varietal development

Systematic efforts towards varietal improvement in mungbean in India started in the third decade of 20th century. The initial phase of this programme aimed at improving locally adapted but genetically variable populations, mainly by the methods of pure line and mass selections with major emphasis on traits other than yield, resulting in the release of large number of pure lines, some of which are still cultivated in certain parts of the country. The emphasis was gradually shifted towards hybridization and selection, later followed by distant hybridization in the last two decades. Using different methods of breeding, 148 varieties have been developed in mungbean and 117 in urdbean till 2016 (Table 4).

Hybridization

Hybridization followed by pedigree method of breeding has led to development of maximum number of varieties in both mungbean and urdbean till 2016. In mungbean, 91 varieties have been bred through hybridization while in urdbean 71 varieties have been developed (Table 4).

Table 4. Number of mungbean and urdbean varieties released in the country till date by using different breeding methods

Method	No. of varieties	Varieties developed before 1985	Varieties developed after 1985
Mungbean			
Selection	45	33	12
Mutation	12	04	08
Hybridization	91	23	68
Total	148	60	88
Urdbean			
Selection	42	28	14
Mutation	04	02	02
Hybridization	71	9	62
Total	117	39	78

Intra-specific hybridization

The first variety of mungbean, 'Type 1' was developed in the year 1936. This was developed from local selection of Muzaffarpur, Bihar which had been extensively utilized in hybridization programme to develop mungbean varieties T 2, K 851 and T 44 and Sunaina. Being a short duration variety and possessing good seed quality, 'T 44' became very popular in Spring/Summer season. Pusa Baisakhi was used later to develop PIMS 4 and Jyoti. Two varieties of mungbean, ML 1 and ML 5 were developed from PAU, Ludhiana during the early 1970s and these were further used to develop ML 131, ML 267, ML 337 and ML 23. During the same period a variety Mohini (S 8) was developed through hybridization between T 2 and BR 2. Iranian germplasm PS 16 and S-8 were used in hybridization programme to develop KM-1, which became a very popular variety of Southern Zone of the country. Large seeded varieties of mungbean, Pusa Vishal, Pant moong 5 and SML 668 were developed from the selection of AVRDC material.

The recent period (2006-15) has seen the development of largely photo- and thermo period tolerant varieties in mungbean. Lately, the focus of breeders shifted towards development of short duration, photo- and thermo period-insensitive varieties of mungbean coupled with resistance to major biotic stresses *viz.,* yellow mosaic disease and powdery mildew, which contributed significantly to the national mungbean production. For example, KM 2241, HUM 16, MH 2-15 and TMB 37 were other varieties developed through intra specific hybridization and these became very popular among the farmers in short time. The variety PKV AKM 4 developed from a cross between BM4 X PS 16 has also been recommended for two zones, *viz*., Central Zone and South Zone of the country. IPM 02-3 was developed using IPM 99-125 and Pusa Bold 2 and recommended for both Spring and *kharif* seasons. The latest variety, IPM 410-3 (Shikha) has been recommended for summer season in North West Plain Zone as well as Central zone while this has been performing very well in *kharif* season also in North Hill Zone. Likewise other varieties for high yield, YMV resistance were also released which were the products of intraspecific hybridization. IPM 2-14 is one such highly promising variety which has been released for *spring* cultivation in South Zone of the country and is gaining tremendous popularity. Another variety DGGV-2 developed from the cross Chinamung x TM-98-50 and Pusa 0672 developed from 11/395 x ML 267 were released for South Zone and North Hill Zone, respectively.In mungbean, SML 668 was the leading variety until 2014-15 accounting for 22.6-31.4% of the indented breeder seed. However, it was replaced by IPM 02-3 at the top with a share of 26.9% during 2015-16. The other leading varieties of mungbean in seed chain are GM 4, IPM 2-14, Pant Moong-5, Samrat, HUM 16 and Meha (Table 5).

Table 5. Share of top ten indenting varieties of mungbean and urdbean during 2010-15.

Crop	Share of top ten varieties (%)	Prominent varieties in seed chain
Mungbean	65.3 (2011-12)-79.8 (2015-16)	IPM 02-3, SML 668, GM 4, HUM 16, IPM 2-14, Samrat, Pant Moong 5,Meha
Urdbean	58.5 (2011-12)-81.5(2015-16)	Pant U 31, IPU 02-43, KU 96-3, TAU 1, LBG 752, KU 300, Uttara

The top ten varieties of mungbean are currently contributing to 80% of the total seed indent in mungbean in the country. These had a share of 65.3 per cent in 2011-12 which increased to 79.8 per cent in 2015-16, IPM 02-3 topping the list by contributing 26.9% of the total seed indent.

Despite tremendous progress in varietal development programme, it is also true that most of the varieties developed so far have been developed from a limited number of germplasm lines. Pedigree analysis of mungbean varieties revealed that very limited genetic variability has been exploited in their breeding programme. For example, T44 has been used extensively in mungbean varietal development programme in India and it is one of the parents for > 15% mungbean varieties. This indicates about the narrow genetic base of the released cultivars and necessitates use of germplasm lines as well as exploitation of wild gene pool for widening the genetic base of these crops.

In urdbean also, a large number of varieties such as T 27, T 77 and T 9 were developed from Uttar Pradesh and Coimbatore in Tamil Nadu during 1943-1953. Establishment of All India Co-ordinated Pulses Improvement Project (AICPIP) in 1967 provided breeders an access to improved germplasm and an opportunity to test their improved breeding lines in multilocation evaluation across the country. As a result, more than 85 varieties of urdbean were developed. Before 1970 many varieties of urdbean were developed from the locally adapted varieties. Among these T 9, ADT 1 and Co 1 were most important lines as they were not only preferred by farmers but had been used extensively in breeding programme to develop several varieties. For example, UPU 1 and UPU 2, selections of T 9 were used in hybridization programme to develop short duration and MYMV resistant varieties Pant Urd 19 and Pant Urd 30. KM 1 was the first variety developed through hybridization in the year 1977. Type 9 in combination with L 64, Sel. 1, Line 400, NP 19, and 7378/2 led to development of urdbean varieties KU 1, Narendra Urd 1, WBG 26, IPU 94-1 and KU 300, respectively. Similarly, LBG 17, Pant U 35 and KU 301 are also derived from crosses Netinminumum x Chikkuduminumu, UPU 3 x Pant U 19 and 7570/7 x Sel.1, respectively. Varieties KM 1 and ADT 4 are the products of three way crosses (G 31 x Khargone 3) x G 31 and (T 9 x ADT 2) x Pant U 19. Like in mungbean, pedigree analysis of released cultivars in urdbean also indicated that a small number of parents with high degree of relatedness were repeatedly used in crossing programme. More than 60 per cent of varieties in urdbean have Type 9 as one of the ancestors in their pedigree.

Two photo-thermo tolerant short duration and MYMV resistant varieties Pant U-31 and Pant U-40 developed by Pantnagar were found suitable for both kharif and spring season as pure culture as well as mixed with cereals. At present Pant U-31 is the most widely cultivated variety in India across the urdbean growing states in different seasons. In Andhra Pradesh and Odisha it is grown in both rabi and kharif seasons across the state. Its resistance to MYMV is stable across the states and seasons in the country. It is occupying number one position in seed production chain since 2012-13 accounting for 8.3% (2012-13), 17.9% (2013-14), 18.1% (2014-15) and 32.5% (2015-16) of the indented breeder seed, respectively. In urdbean, contribution of topmost 10 varieties to breeder seed was lowest (58.5%) in the year 2011-12 which rose to 81.5% in 2015-16. The other leading varieties under seed chain are IPU 02-43, KU 96-3, TAU 1, LBG 752, KU 300 and Uttara (Table 5).

Inter-specific hybridization

Wild relatives offer a number of useful gens not found in cultivated germplasm (Table 6). Distant hybridization has led to development of a number of promising advanced breeding lines for *Vigna* improvement programme. Mungbean × urdbean crosses have been routinely attempted as the derivatives from mungbean × urdbean crosses exhibit many desirable features such as lodging resistance, synchrony in podding and non-shattering pods (Reddy and Singh 1990). Derivatives from mungbean x urdbean crosses have also been reported to exhibit higher level of yellow mosaic disease resistance caused by mungbean yellow mosaic virus (MYMV) (Gill et al. 1983). Several other traits such as long pods, number of seeds per pod and erect plant type may be transferred from mungbean to urdbean while sympodial bearing and multiple clusters per peduncle may be transferred from urdbean to mungbean. Singh and Dikshit (2002) successfully introgressed yield genes in mungbean from urdbean imparting 15-60% yield advantage. Similarly, progenies from mungbean × ricebean and mungbean × *V. radiata* var. *sublobata* crosses were also recovered which exhibited high degree of resistance to MYMV (Verma and Brar 1996). Successful inter-specific crosses between *Vigna unguiculata* and *V. vexillata* have also been reported. However, it was not confirmed through backcross breeding whether F1 developed were true F1 hybrids or not (Gomathinayagam et al. 1998). Tyagi and Chawla (1999) also reported successful crosses between *V. radiata* and *V. unguiculata* using in vitro culture techniques. Gibberellic acid treatment sustained the pods for 9-10 days, which were then used for embryo culture. About 10% of total embryos resulted in plantlet formation. In this case also, the authors did not report further growth and culture of these plantlets and therefore, it is not certain whether the crosses were true hybrids. Large number of promising material with novel traits in both mungbean and urdbean has been developed. The variability generated through these crosses for different agronomic traits are unique as such extreme types are not available in the collection of either mungbean or urdbean germplasm (Singh and Singh 1998; Singh and Dixit 2002). The derivatives from mungbean × urdbean crosses exhibit many desirable features such as lodging resistance, synchrony in podding and non-shattering (Reddy and Singh, 1990). The major post-harvest constraint of food legumes is susceptibility to bruchids (*Callosobruchus chinensis* L.) that eat seeds in storage. One accession of wild mungbean (*Vigna radiata* var. *sublobata*) exhibited complete resistance to azuki bean weevils and cowpea weevils (Fujii et al., 1989) which has been successfully used in breeding program (Tomooka et al. 1992). *Vigna mungo* var. *silvestris* is also reported to be immune to bruchids (Fujii et al. 1989 and Dongre et al. 1996).

Although successful transfer of many desirable traits has been successfully accomplished in *Vigna* species from wild genetic resources, the actual release of new cultivars from distant crosses is scanty. Low fertility level in early generations allows only a limited recombination and usually leaves a small population for selection. Pant Mung 4 is the first variety developed from interspecific hybridization. Subsequently, five more varieties have been released. All of these have inherited MYMV resistance genes from blackgram in addition to improved plant types balanced vegetative growth, some degree of photothermo insensitivity and synchronous maturity. Pant Mung 4 has been developed by G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. This variety has been released for the North East Plain Zone of the zone of the country. IPM 99-125 has been developed and released in 2004 for the North East Plain Zone of India by the Indian Institute of Pulses Research, Kanpur and currently is one of the most popular varieties of mungbean in India. Variety HUM 1 developed by Banaras Hindu University (BHU), Varanasi has been released for cultivation in the Central and South zones of the country.

In urdbean, Mash 1008 was developed by Punjab Agricultural University Ludhiana involving mungbean and urdbean cross and was released for the North

Table 6. Potential sources of alien variation in Vigna

Character	Species	References
Resistance to bruchid	*V. riukinensis* *V. reflexo-pilosa*	Tomooka et al. 1992 Tomooka et al. 1992
	V. radiata var. *sublobata*	Fujii and Miyazaki 1987; Kaga and Ishimoto 1998, Miyagi et al. 2004
	V. umbellata	Tomooka et al. 2000; Kashiwaba et al. 2003; Somta et al. 2006
	V. tenuicaulis	Tomooka et al. 2000
	V. nepalensis	Somta et al. 2008a
Resistance to powdery mildew	*V. stipulaceae* *V. reflexo-pilosa* var. *glabra*	Tomooka et al. 2006a Egawa et al. 1996
Low trypsin inhibitor activity	*V. tenuicaulis*	Konarev et al. 2002
Chymotrypsin absent	*V. grandiflora*	Konarev et al. 2002
High methionine content	*V. radiata* var. *sublobata*	AVRDC 1987; Babu et al. 1988
High photosynthetic efficiency & drought tolerance	*V. radiata* var. *sublobata*	Ignacimuthu and Babu 1987
drought tolerance	*V. aconitifolia*	Jain and Mehra 1980
Heat tolerance	*V. aconitifolia*	Tomooka et al. 2001
	V. riukinensis	Egawa et al. 1999
Insect resistance	*V. unguiculata* ssp. *dekindtiana*	Ehlers Hall 1997 var. *pubescens*
YMV resistance	*V. radiata* var. *sublobata*	Singh and Ahuja 1977
Cucumber mosaic virus resistance	*V. reflexo-pilosa* var. *glabrescens*	Egawa et al. 1996
Bean fly resistance	*V. reflexo-pilosa*	Egawa et al. 1996
High tolerance to saline and alkaline soils	*V. radiata* var. *sublobata*	Lawn et al. 1988
Resistance to pod bug	*V. unguiculata* ssp. *dekindtiana*	Koona et al. 2002
Resistance to cowpea insects pests	*V. vexilata*	Birch et al. 1986; IITA 1988
No. of seeds/plant and pods/plant	*V. radiata* var. *sublobata*	Reddy and Singh 1990
Resistance to Yellow Mosaic Virus	*V. radiata* var. *sublobata* *V. trilobata* *V. umbellata, V. trilobata*, *V. mungo*	Reddy and Singh 1990; Pal et al. 2000 Nagaraj et al. 1981 Pandiyan et al. 2008
Photo thermo-insensitivity	*V. umbellata, V. glabrescens*	Pratap 2012b

Adopted and modified from Pratap et al. (2014)

West Plain Zone in 2008. Two other urdbean varieties were developed by introgressing desirable traits from *V. mungo* var. *sylvestris*. Using the above varieties developed from distant crosses, some other promising materials hves also been generated. For example, using IPM 99-125 as one of the parents, genotypes IPM 02-1 and IPM 03-1 were developed in mungbean at IIPR, Kanpur which were further used in development of two extra early mungbean genotypes, IPM 205-7 and IPM 409-4, which mature in about 52-55 days (Pratap et al. 2013a). IPM 205-7 (Virat) has been released recently for cultivation in Punjab, Haryana, Uttar Pradsh, Bihar, Jharkhand, Odisha, Tamil Nadu and Madhya Pradesh. Both these genotypes will help in horizontal expansion of mungbean cultivation in India, especially during the spring/summer season in the northern India as well as in rice fallows in peninsular India. Recognizing their

Table 7. Varieties of mungbean and urdbean developed through interspecific hybridization

Crop/variety	Pedigree	Year of release	Area of adaptation	Developed by
Mungbean				
Pant Mung-4	T-44 x UPU-2	1997	NEPZ	GBPUAT, Pantnagar
HUM-1	BHUM-1 x Pant U-30	1999	CZ & SZ	BHU, Varanasi
Meha	Pant Mung-2 x AMP-36	2004	NEPZ	IIPR, Kanpur
Pant Moong-6	Pant Mung-2 x AMP-36	2007	NHZ	GBPUAT, Pantnagar
IPM02-3	IPM 99-125 x Pusa Bold-2	2009	NWPZ	IIPR, Kanpur
IPM 02-14	IPM99-125 x Pusa Bold-2	2010	SZ	IIPR, Kanpur
Urdbean				
Mash 118	Mungbean x Urdbean	2008	NEPZ	PAU,Ludhiana
Vamban-7	Vamban-3 x *V. mungo* var. *sylvestris*	2011	SZ	TNAU, Vamban
TU-40	TU 94-2 x *V. mungo* var. *sylvestris*	2011		BARC, Trombay

Note: UPU-2 and Pant U-30 are black gram cultivars. AMP-36 is a derivative of K-851 x MCK-2. IPM 99-125 is derivative of Pant Mung-2 x AMP-36

potential, IPM 205-7 was also registered as INGR 11043 and IPM 409-4 as INGR 11044 by the National Bureau of Plant Genetic Resources (ICAR), New Delhi, both for extra early maturity (Pratap et al. 2013b).

At Pantnagar, several lines of both mungbean and black gram type from an interspecific cross of mungbean *V. radiata* (cv. BDYR-1) x black gram (cv. DPU 88-31) were recovered. BDYR-1, is a large seeded exotic cultivar susceptible to foliar diseases. DPU 88-31 is an elite cultivar of black gram which is free from foliar diseases of mungbean. The recovery of black gram type of progenies from such a cross is the first report. Earlier workers reported recovery of mungbean type of progenies as the black gram type of plants did not survive in the early segregating (F_2/F_3) generations. Other successful crosses reported in genus *Vigna* are; *V. radiata* x *V. radiata* var. *sublobata* (Ahuja and Singh 1977) and *V. mungo* x *V. mungo* var. *sylvestris* (Singh 1982), which have been used for the genetic enhancement of the respective cultivated species, (Singh 1990; Reddy and Singh 1989; Parida and Singh 1985). Two varieties of black gram; Vamban-7 and TU-40 have been developed, respectively from Vamban-3 x *V. mungo* var. *sylvestris* and TU 94-2 x V. mungo var sylvestris and released in 2011 for SZ of the country (Table 9). Vamban 7 is resistant to MYMV and powdery mildew and recommended for cultivation in kharif season and TU 40 is resistant to powdery mildew and recommended for cultivation for rabi season.

Mutation breeding

Induced mutations have been found useful in creating useful variability for yield traits, plant type and resistance to various stresses. So far 52 varieties have been developed through mutation breeding in different pulse crops among which 8 are in mungbean and 2 in urdbean developed after 1985 (Table 4). Most of these have been developed from already released and adapted varieties. In general, gamma-irradiation has been used and very rarely chemical mutagens have been used. The mutant varieties are improvement over their maternal parent and/or standard check for character(s) such as plant type, seed size, seed colour, maturity duration and resistance to disease(s).

Mutation breeding has resulted in development of Pant Moong 2, MUM 2, Co 4, LGG 407, LGG 405 and BM 4 in mungbean and Prasadand Ujala in blackgram. Pant Mung-2 is a mutant of ML-26. It is moderately resistant to MYMV and has shining green seeds. It was higher yielding to the parental cultivar and was released in 1982. This variety is very popular in central U.P. and is grown after harvest of potato. LGG-450 (Pushkara) is a mutant of Pant Mung-2 for tolerance to pre-harvest sprouting. Black gram variety Vamban-2 is a mutant of Type-9 and it tolerant to drought and resistant to MYMV. Prasad (B 3-8-8) and Ujala (OBG-17) varieties of black gram are mutants of Type-9 and B 3-8-8, respectively. Both of these were released in 2005 for *kharif* and *rabi* season and were resistant to MYMV.

Use of molecular markers in improvement of pulses

Although not much breeding work has been done till now in mungbean and urdbean using molecular tools except marker transferability, genetic diversity. Considerable work has been in India at Indian Institute of Pulses Research, Kanpur and elsewhere recently in developing molecular markers for marker assisted selection. Besides using molecular markers for confirmation of hybridity status of F1 hybrids, Gupta et al. (2013) and Pratap et al. (216) studied transferability of simple sequence repeat (SSR) to increase the availability of molecular markers for germplasm evaluation, genetic analysis and new cultivar development in blackgram. In a study by Gupta et al. (2013) it was found that MYMV resistance is governed by a single dominant gene in blackgram genotype DPU 88-31. The F2 population from the same cross was also used to tag and map the MYMV resistance gene using SSR markers. Out of 361 markers, 31 were found polymorphic between the parents. However, marker CEDG 180 was found to be linked with resistance gene following the bulked segregant analysis. This marker was mapped in the F2 mapping population of 168 individuals at a map distance of 12.9 cm. In another study by Pratap et al. (2015), 41 wild and 12 cultivated accessions of 13 Vigna species were genotyped using 53 polymorphic microsatellite markers. A total of 539 alleles were detected among 53 accessions at all loci with an average 10.16 alleles per locus. The UPGMA revealed five major clusters accommodating 96 % of the accessions. The model-based population structure analysis grouped 53 accessions of *Vigna* into five genetically distinct sub-populations (K = 5) based on maximum K values.

Impact of research in crop production

Mungbean is cultivated most extensively in South and South-East Asia where about 85% of its production is consumed. Mungbean is also grown in Australia, Peru, Ecuador, USA, Kenya and Malawi and Caribbean, African and Middle Eastern countries. India is the largest producer of this crop and alone accounts for about 65% of the world acreage and 54% of the world production. In India, it is grown in different seasons; in rainfed condition in *kharif* (rainy) season, on residual moisture in rice fallows and in irrigated conditions in Spring/Summer. The major states producing mungbean are Rajasthan, Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Odisha, Tamil Nadu, Bihar and Uttar Pradesh.

Area, production as well as productivity of mungbean in India have seen a consistent upward trend since 1960s and the production increased from 0.60 million tones in 1964-65 to about 1.55 million tones in 2015-16 (Table 8). Likewise, development of improved varieties and technologies also helped in increasing productivity from about 280 to 500 kg/ha. During the last decade (2006-15), a phenomenal growth in mungbean area and production has been witnessed in non-traditional niches, especially in summer, spring and rice fallow cultivation. Area in non-traditional niches has steadily increased over the years from the level of 0.61 million ha in 2009-10 to 1.0 million ha in 2014-15. Likewise, the production has also witnessed an upward trend as it increased to more than double from 2.5 lakh tonnes in 2009-10 to 6.36 lakh tonnes in 2014-15 (Table 9, Fig. 1) corresponding to a growth rate of 15-20% per annum during the period. This could be achieved due to cultivation of newly released higher yielding cultivars and development of specific production technologies for non-traditional niches. The productivity of mungbean increased from 409 kg/ha (2009-10) to 640 kg/ha (2014-15). The productivity of

Table 8. Trends in area, production and yield of mungbean and urdbean in India in last 50 years

Year	Mungbean			Urdbean		
	Area (mha)	Production (m tonnes)	Productivity (kg/ha)	Area (mha)	Production (m tonnes)	Productivity (kg/ha)
1965-66	1.99	0.60	302	1.84	0.55	300
1970-71	2.07	0.70	339	2.07	0.66	318
1975-76	2.52	0.80	334	2.16	0.76	350
1980-81	2.83	0.98	344	2.83	0.96	339
1985-86	3.00	1.18	392	3.19	1.24	389
1990-91	3.36	1.38	413	3.48	1.65	473
1995-96	2.71	0.82	303	2.80	1.32	471
2000-01	3.08	1.02	340	3.01	1.30	431
2005-06	3.20	0.95	304	2.97	1.25	463
2010-11	3.55	1.80	512	3.26	1.76	534
2011-12	3.38	1.63	492	3.21	1.77	572
2012-13	2.71	1.19	469	3.11	1.90	642
2013-14	3.38	1.60	474	3.06	1.70	555
2014-15	3.02	1.50	498	3.24	1.96	604

Table 9. Season-wise area, production and productivity of mungbean and urdbean in India during last 6 years

Crop	2009-10			2011-12			2012-13			2013-14			2014-15		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Mungbean															
Mungbean (*kharif*)	24.6	4.4	180	26.7	12.9	482	26.1	12.4	474	23.4	9.58	410	22.5	13.24	585
Mungbean (spring/summer/ *rabi*/rice fallow)	6.1	2.5	409	7.5	4.1	555	7.7	3.9	508	10.5	6.45	620	9.95	6.36	640
Mungbean total	30.7	6.9	224	33.8	16.3	492	33.8	16.1	476	33.9	16.1	474	32.4	19.6	604
Urdbean															
Urdbean (*kharif*)	22.3	8.10	363	24.1	12.7	530	24.4	14.8	606	23.5	11.5	490	24.8	12.8	516
Urdbean (spring summer/*rabi*/rice fallow)	7.3	4.2	586	8.8	5.5	624	6.9	4.7	679	7.1	5.5	768	7.6	6.8	891
Urdbean total	29.6	12.3	418	32.9	18.3	555	31.1	19.0	642	30.6	17.0	555	32.4	19.6	604

Where; A= lakh ha, P= lakh tonnes; Y=kg/ha

summer crop has been especially better which was 1.3 times higher than that of the kharif crop during last triennium (Table 9). This increase has helped in improving the national average of mungbean productivity from 354 kg/ha in 2005-08 to 461 kg/ha during 2011-14. Encouraged by its profitability, summer mungbean now accounts for substantial proportion (33%) of the total mungbean production in the country which mainly comes from Punjab, Haryana, Western Uttar Pradesh, Madhya Pradesh, Gujarat, Bihar, West Bengal, Assam and Tamil Nadu. The Summer mungbean technology has the highest visible impact than any other technology in pulses in general and these crop in particular.

Blackgram or urdbean is cultivated in different seasons in India. As a mixture it is grown in rainfed condition with cereals, pigeonpea, etc. in *kharif* season while under irrigated condition in *rabi* and spring/ Summer season, it is generally cultivated as a pure crop. It is also grown on residual moisture in *rabi* in eastern and southern parts of country. In India, urdbean is predominantly cultivated in Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Rajasthan, West Bengal and Odisha. Besides India, urdbean is also cultivated in Pakistan, Bangladesh, Sri Lanka and Myanmmar. As in mungbean, the area under urdbean also increased considerably from 1.84 million ha in 1965-66 to 3.24 million ha in 2014-15 (Table 8, Fig. 2). Likewise, the production increased by about four times from 0.55 million tones to 1.96 million tonnes in 2014-15 (Table 1) while the productivity increased from 300 kg/ha to 604 kg/ha during the same period. Between 1970s and 2010s alone an increase of >1.0 m ha area and > 1.0 m tonnes of production with an increase of 210 kg/ha in average productivity has been achieved. This increase in productivity has been possible mainly on account of development of new high yielding varieties and area specific technologies. Like mungbean, the increase in productivity has been more in case of *rabi*/Spring sown crops where it has gradually increased from 580 kg/ha in 2001-02 to 890 kg/ha in 2014-15 although there has been a considerable decrease in area during the corresponding period. However, due to increase in the productivity, the total production during *rabi*/Spring season also increased from 5.19 lakh tones to 6.78 lakh tones during the same period. Likewise in mungbean, the increase in productivity in urdbean has been high in Spring/Summer/*rabi* crops as compared to *kharif* season crop. During the last 6 years the urdbean productivity increased from 586 kg/ha (2009-10) to 891 kg/ha (2015-16) while in *kharif* season it increased from 363 kg/ha to 516 kg/ha only. There was a proportionate increase in production also in different seasons although the area kept fluctuating.

Conclusions and future strategy

Considerable progress has been made towards the development of high yielding, stress resistant and short-duration varieties in mungbean and urdbean and their impact has also been realized in both, production and productivity which have almost doubled in the past

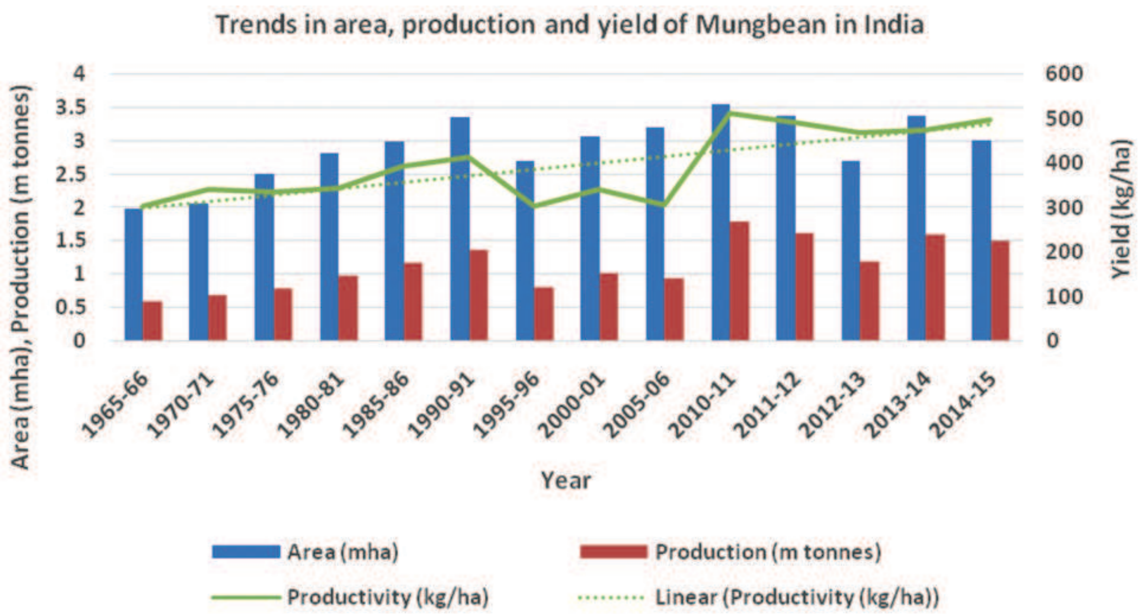

Fig. 1.

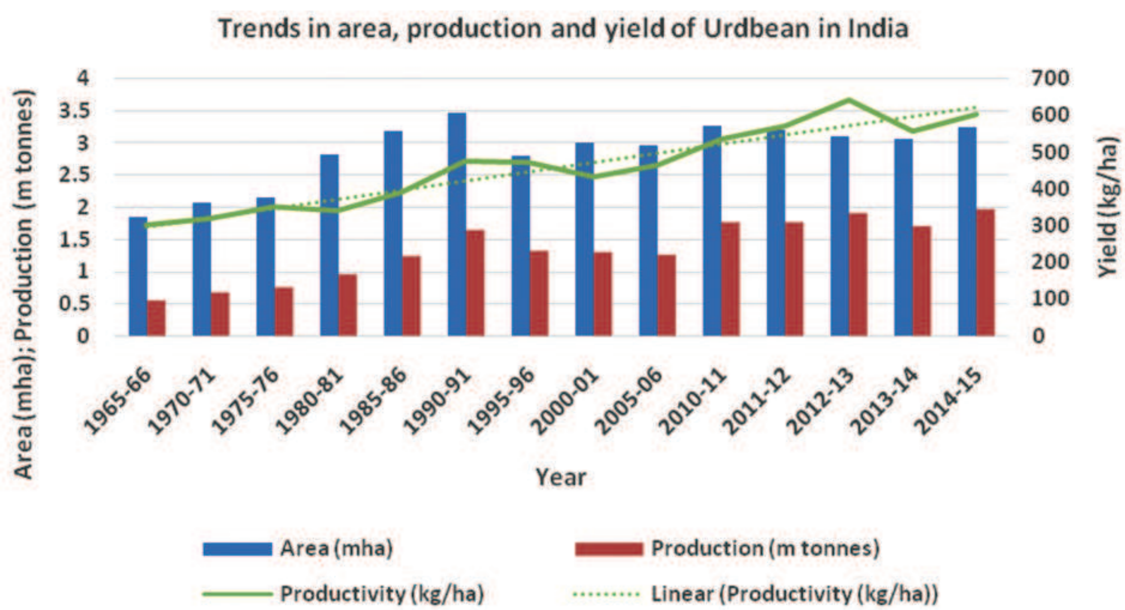

Fig. 2.

50 years. In general, the varieties of these crops developed till date are superior in at least one or more important traits like early maturity, plant type, resistance to one or more highly prevalent diseases (rarely more than two diseases) with improved grain yield. However, very few varieties have been developed for specific niches such as rice fallow and summer season after the harvest of wheat. Likewise, while remarkable progress has been made in collection, evaluation, characterization and documen-tation of germplasm, their use in breeding superior varieties is not up to the expectation. Most of the varieties are developed at experimental stations with very good and well fertilized land under optimum conditions while their yield under harsh and input deficient soils at farmers fields are affected seriously. Therefore, it is suggested that the pulse varieties should be developed for the conditions which are representative of farmers' field.

A strategy document for achieving self sufficiency in pulses in the country envisages mungbean and urdbean as the most important future contributors to pulses. There is a tremendous scope of horizontal as well as vertical expansion in both these crops besides diversifying their uses for market value. However, the future mungbean and urdbean development programme needs to be structured keeping in view the changing climate scenario, climate and soil adversities, decreasing fertile land resources, competition from other crops. Mungbean and urdbean breeding programmes need to be thoroughly revised so to achieve yield breakthrough to make these crops remunerative to farmers.

There are a number of research issues which need to be addressed while working for development of new varieties in these crops. Pre-harvest sprouting tolerance, bruchid resistance and increasing nutritive value are some of the areas which still remain largely untouched and need more attention. A major thrust is required on incorporation of pre-harvest sprouting and bruchid resistance, pyramiding of genes for resistance to major insect-pests (thrips, jassids) and diseases (MYMV, PM and CLS) for which resistance level is not high in cultivated germplasm. Identification of diverse germplasm sources for important economic traits and plant types and accessing desirable genes from wild species should be a major focus. Development of short duration varieties with distinct vegetative and reproductive phase for fitting the crop in cereal- cereal cropping system as well in those areas where these can be effectively taken as a catch crop will further increase their area and productivity. In mungbean, breeding short duration (52-55 days) varieties for Summer season with minimum yield penalty, longer duration genotypes (65-75 days) for kharif season, and varieties with high initial growth vigour for rice fallow will promote this crop in new areas. Likewise, reducing urdbean crop duration to 70-75 days will fit it in multiple cropping systems. Mungbean and urdbean are such crops which are grown in almost every corner of the country in different seasons *viz*., Spring, Summer, *kharif*, and winter season under varying agro-ecological conditions and different temperature regimes. The performance of high yielding cultivars with thermo- and photo sensitivity may not be at par with their genetic potential across locations in India. Therefore, development of thermo- and photo-insensitive varieties is of utmost importance in ongoing breeding programs. Such varieties can be effectively taken as a catch crop that will further increase their area and production. Redefining crop geometry in case of short duration and less biomass varieties, fitting new varieties in most popular cropping systems, reducing water usage through micro-irrigation systems and resource conservation practices will require more impetus.

In the past decade, proactive and coordinated efforts of the international legume community have ensured a significant progress in the development of genomic resources of these crops which have led to a better understanding of their genome structure. These have also offered new possibilities for genetic improvement of not only these crops but also several other species, especially those where their development is costly. While the cost effective, polymorphic and reproducible markers such as SSRs, SNPs, etc. can be used by breeders in development of improved cultivars through marker assisted breeding employing MAS, MARS and MABC, high throughput sequencing can accelerate the development of new molecular markers. The marker-trait association will enable biotechnologists to more rapidly and precisely manipulate target genes underlying key agronomic traits, especially a series of abiotic and biotic stresses limiting crop productivity. This will be especially useful in developing such genotypes which suit the marginal environments of food legume growing areas of the world.

There have also been spectacular advances in demonstrating alleles from wild relatives of crops to have potential to improve the performance of crops. This is likely to provide a major stimulus for the use of diverse genetic material of crop relatives for incorporation into new crop cultivars. The application of marker technologies to the re-domestication of crops by exploiting the potential of favourable alleles existing in the wild relatives of crops provides an excellent opportunity for achieving necessary advances in pulse improvement. Mungbean and urdbean as pulse crops have tremendous potential to increase horizontally as well as vertically and with focused research efforts, their genetic potential may be increased manifolds. This will not only ensure self sufficiency in pulses in the country but will also have everlasting effects on soil health and environmental sustainability. To achieve the goal of self sufficiency, a quantum jump in yield potential in these crops is essential, which is possible through application of integrated breeding approaches including cutting edge technologies for identification and introgression of yield genes and QTLs based on sound genotyping and phenotyping.

Declaration

The authors declare no conflict of interest.

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