Theor. Appl. Genet. 59, 1-10 (1981)

Review

Breeding for Resistance to Diseases in Greengram and Blackgram

D.P. Singh
Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (India)

Summary. This review is given on the origin and interrelationship of blackgram and greengram: the symptoms, mode of transmission, and host range of important diseases, namely: mungbean yellow mosaic virus, leaf crinkle virus, leaf curl virus, mosaic mottle virus, *Cercospora* leaf spot, powdery mildew, root and stem rots, bacterial leaf spot and halo blight. The screening for resistance, sources of resistance, including interspecific hybridization, and induced mutations, as well as the genetics of resistance are treated along with suggestions for future breeding strategies of these crops.

Key words: *Vigna radiata* – *Vigna mungo* – Blackgram – Greengram – Disease resistance

Introduction

The genus *Vigna* comprises 100 to 150 species. Of these, greengram or mungbean and blackgram or urdbean are the most widely cultivated. Both of these species were classified in the genus *Phaseolus* until Wilczek (1954) created the new name *Vigna radiata* (L.) Wilczek for *Phaseolus aureus* (L.), greengram and Hepper (1956) gave the new name *Vigna mungo* (L.) Hepper for *Phaseolus mungo* (L.), blackgram. Methods of differentiation between the genera *Phaseolus* and *Vigna* have been reviewed by Evans (1975) and Marechal (1975).

Greengram is relatively drought tolerant. It is cultivated in India, Pakistan, Bangladesh, Srilanka, Thailand, Laos, Kampuchea, Vietnam, eastern Malaysia, Southern China and in the relatively dry eastern parts of Java, (Jain and Mehra 1978). In the recent past it has been introduced into the eastern and central parts of Africa, the West Indies and the U.S.A. It is also grown in the Philippines, Nepal, Taiwan and Indonesia. Blackgram has greater water requirements than greengram. It is grown in India, Pakistan, Srilanka and Burma (Jain and Mehra 1978).

In India, greengram and Blackgram are mainly grown as a mixture and rarely as pure cultures. The average yields of the two crops are very low in tropical and sub-tropical Asia, including India. This is because of inherently low yielding potential of the varieties and their susceptibility to diseases. The breeding for resistance to diseases in the two crops needs to be taken up vigorously to further increase yield. A compilation of existing scanty information on resistance breeding is worthwhile. Therefore, in addition to reviewing the origin and interrelationship of *Vigna radiata* and *Vigna mungo*, information on symptoms, host range, mode of transmission of important diseases, screening for resistance, sources of resistance including varietal hybridization, interspecific hybridization and induced mutations is compiled together with the genetics of resistance of important diseases.

Origin and Interrelationship of *Vigna radiata* and *V. mungo*

According to de Candolle (1884), Vavilov (1926) and Zukovskij (1962) both greengram and blackgram originate from the Indian subcontinent. Maximum diversity among related species is limited to the upper western ghats and deccan hills. A secondary centre of diversity exists in Bihar (India). The present Monghyr city of Bihar was once called Muda-giri or the mung hills (De 1976). Singh et al. (1975) observed variable forms of green- and blackgram in the eastern ghats and in the area from Madhya Pradesh (India) southwards.

The *Vigna sublobata* appears to be the most probable progenitor of both *V. radiata* and *V. mungo* (Zukovskij 1962) and occurs wild in India and Indonesia. Natural population of *V. sublobata* are supposed to have differentiated during domestication into the two crop plants *V. radiata* and *V. mungo* (Jain and Mehra 1978). Primitive versions of both *V. radiata* and *V. mungo* have been collected by Singh et al. (1975). The greengram has spreading or reflexed pods with small hairs, globose seeds and flat hilums. Blackgram carriers erect or suberect pods with long hairs. Its seeds are larger, oblong and smooth, with a concave hilum (Rachie and Roberts 1974).

0040-5752/81/0059/0001/$ 2.00

Symptoms, Host Range and Mode of Transmission of Important Diseases

Virus diseases

Mungbean Yellow Mosaic Virus (MYMV)

The mungbean yellow mosaic virus is very devastating in tropical and sub-tropical Asia. In addition to attacking greengram, it causes considerable losses in soybean and blackgram (Nene 1969; 1970; 1972; Nariani 1960; Varma et al., 1973; Grewal 1978). Yield losses up to 100 per cent have been reported after artificial inoculation (Nair 1971; Vohra 1976). Rathi and Nene (1974) found the host range of MYMV to be restricted to species belonging to the families *Leguminosae, Compositae* and *Gramineae.*

Nariani (1960) interconnected yellow mosaic on greengram with a virus. Nene (1968) named it mungbean yellow mosaic virus. This virus has also been referred to as yellow mosaic virus (Ahmad and Harwood 1973; Virmani et al. 1976).

The first symptoms appear on young leaves as yellow specks or spots. The leaf emerging from the apex shows bright yellow patches interspersed with green areas. In severe cases there is complete yellowing of the leaves and infected plants are stunted. They bear few flowers and pods and mature late. Nair et al. (1974) noted necrotic and yellow mottle in blackgram to be caused by the same virus. The necrotic mottling is a type of resistant reaction against MYMV.

The MYMV is transmitted by whitefly, *Bemisia tabaci* Genn. (Nariani 1960; Nene 1972) but not through sap (Nariani 1960; Nair (1971), seed or soil (Nair 1971). The whitefly is a very efficient vector, acquiring and inoculating the virus in certain hosts within 10 to 15 minutes. For 100 per cent transmission, 10 viruliferous flies per plant are required (Nair 1971; Nene 1973).

Leaf Crinkle Virus

Leaf crinkle virus disease of blackgram was first reported in 1966 Williams et al. (1968). The infected plants become stunted and develop rugosity and crinkling on affected leaves (Nene 1968; Williams et al. 1968). The inflorescence of the affected plants bears a large number of small flower buds with thick, dark green sepals giving a bushy appearance (Grewall 1978). It produces few pods (Nene 1968; Williams et al., 1968), a reduction due to pollen sterility caused by the virus (Narayanaswamy and Jaganathan 1975).

The virus is seed, sap and aphid (*Aphis craccivora*, Koch. and *A. gossypii* Clov.) transmissible (Nene 1972; Kolte and Nene (1972; Dhingra 1975). For effective transimission a very short acquisition feeding period of 30 seconds to two minutes preceded by a pre-acquisition fasting was found necessary. The host range of leaf crinkle virus is limited to greengram, blackgram, mothbean and cowpea (Nene 1972; Kolte and Nene 1975; Grewal 1978). The virus may cause 62 to 100 per cent losses depending on plant stage infected (Nene 1972).

Mosaic Mottle Virus

This disease was described by Shahare and Raychaudhary (1963). It is characterized by a mosaic and pattern of broad patches of light and dark green areas and blistering of leaf blade. Affected plants show reduction in overall growth, generally interconnected with excessive branching. In cases of severe infection the whole inflorescence is changed into leaf-like structures, thereby causing 100 per cent loss in seed yield (Nene 1972). Shahare and Raychaudhary (1963) described the disease as a mosaic and Nene (1972) named it mosaic mottle virus. It can be transmitted by juice (Shahare and Raychaudhary 1963), mechanically, and by seed (Nene 1972). Host range of the virus is confined to the family *Leguminosae* (Shahare and Raychaudhary 1963; Nariani and Kandaswami 1961; Srivastava et al. 1969; AVRDC 1977).

Leaf Curl Virus

Nene described the symptoms of this disease for the first time in 1968. The virus is an important potential killer of plants of blackgram and greengram (Nene 1972). Chlorosis will develop around veins and their branches near the margin of the youngest trifoliate leaf (Nene 1968). The leaf margins are curled downwards, and sometimes rolling and twisting of young leaves can also be observed. The infected plants produce few pods which at late infection might contain small seeds. Transmission proved successful if performed mechanically or by grafting.

Fungal Diseases

Cercospora Leaf Spot (CLS)

It is cuased by *Cercospora canescens* Ell. and Mart. and *C. cruenta* Sacc. and is one of the most important diseases of greengram in the Philippines (Welles 1924; Quebral 1978; Ilag 1978), Bangladesh (Islam 1978), Thailand (Nalampang 1978), Malaysia (Johnson 1970), Nepal (Bharti 1978), Taiwan (AVRDC 1976), and India (Grewal 1978). The pathogen is seed-borne (Grewal 1978).

Spots develop on infected leaves with a somewhat circular to irregular shape. The central area will turn tan or gray with reddish brown or brown to dark brown margins. Lesions vary in size depending on the isolate and the host (Ilag 1978). Rath and Grewal (1973) observed heavy sporulation at 27°C temperature and 96 per cent ralative humidity. The lesions increase in number and size during flowering but increase is most rapid at the pod-filling stage, which in India occurs during September. In susceptible varieties infection increases rapidly, resulting in premature defoliation. The size of pods and seeds is reduced and thus also the yield (Grewal 1978). Yield losses up to 47 per cent have been reported during the warm and wet season (AVRDC 1976).

Powdery Mildew

It is one of the most common diseases in all greengram

growing areas (Park and Yang 1978). It is servere in Thailand (Duangploy 1978), the Philippines (Catedral and Lantican 1978), and in Taiwan (Legaspi et al., 1978). The disease is caused by *Erysiphae polygoni* D.C. It is most severe during the dry season and practically non-existent during the wet season. The temperature from 22 to 26°C and relative humidity from 80 to 88 per cent is favourable for the development of the disease (Ilag 1978).

The fungus attacks all parts of the plant except roots. The initial symptoms are faint, slightly dark areas developing over the leaf, later turning into small, white powdery spots. These spots enlarge, coalesce and develop into a complete coating by a white to dirty-white powder consisting of mycelium and conidia. Defoliation takes place in case of severe infections. Pods are not formed and if formed they bear subnormal seeds. Yield reduction could range from 20 to 40 per cent (legaspi et al. 1978).

Root and Stem Rots

In India *Rhizoctonia bataticola* and *R. solani* are important pathogens which cause rotting of stem and roots of greengram (Grewal 1978). The fungi attack seedlings at the ground level forming localised dark green patches. These coalesce and encircle the whole stem in the case of infection caused by *R. bataticola* while red brown patches are formed in connection with *R. solani*. The infected stem will be too weak to support the plant and the young seedling dies. Ilag (1978) observed rots caused by *R. solani* but also by *Sclerotium rolfsii* in the Philippines.

Welles (1924) reported that the host range of *R. solani* also includes i.a.. soybean, cowpea, tobacco, peanut, common garden beans, maize, egg plant and pepper. The basidial form of the fungus is know as *Thanatephorus cucumeris* (Fr.) Donk and this infects more than 20 host species (Saksena and Dwivedi 1974). Various species of *Fusarium* and *Pythium* also cause root and stem rot diseases (Ilag 1978).

Bacterial Diseases

Bacterial Leaf Spot (BLS) and Halo Blight

Bacterial leaf spot is caused by *Xanthomonas phaseoli* (Smith) Downson. It was observed on blackgram for the first time by Rangaswami and Gowda (1963) in India and on greengram by Fang et al. (1964) in China. The symptoms first appear as superficial eruptions which gradually go deeper in the leaf tissue. Finally, big necrotic areas will develop with a corky or rough surface. Lesions developed on petioles are brown, raised and occur singly or in long streaks (Patel et al. 1972). BLS spreads through seeds (Patel et al. 1972). *Phaseolus vulgaris, P. bracteatus, P. lunatus, Dolichos lablab*, and *Lens esculentum* can also be infected by *X. phaseoli* using artificial inoculations, but the reaction is not as severe as on greengram (Patel and Jindal 1972).

Halo blight of greengram is caused by *Pseudomonas phaseolicola*. It produces water-soaked spots surrounded by a characteristic halo. The organism produces the same symptom on *P. bracteatus, P. alropurpureus, D. lablab, D. biflorus*, and *Ficus religiosa* (Patel and Jindal 1972).

Breeding for Resistance

Screening for Resistance to Different Diseases

Nene et al. (1972) evaluated germplasm of blackgram and greengram for resistance to mungbean yellow mosaic virus. He used alternatively cultivars as NO. 55, Khargaon-3, or Gwalior-18 in blackgram and Jalgaon-781 in greengram as susceptible spreaders. Promising material was reexamined by artificial infection at the pre-flowering stage by covering the rows with muslin cloth cages of 60 × 90 × 120 cm dimensions and releasing 300 viruliferous whiteflies in each cage (Fig. 1). This method was later used by Shukla (1977) for screening the F_2 and F_3 plants. Nene (1972) suggested use of insect proof transparent plastic pickle pots with screwcap for the inoculation of individual plants, a technique used by Shukla (1977) for the inoculation of individual plants of parents and F_1's (Fig. 2). Virmani et al. (1976) identified resistant sources to MYMV by field screening. These varieties also showed resistant/tolerant reaction under glasshouse conditions. We, at Pantnagar,

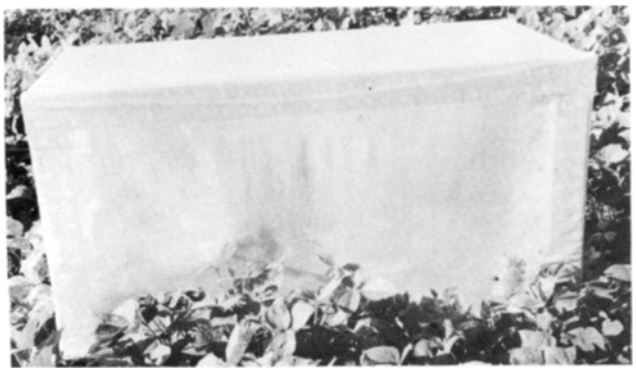

Fig. 1. Iron frame covered with muslin cloth bag for mass-screening against whitefly transmitted MYMV of greengram and blackgram

Fig. 2. Insect proof transparent pickle pots with screwcap used for inoculation of individual plants of greengram and blackgram against whitefly transmitted MYMV

are replicating UL-2 (spreader row for MYMV) at every 5 to 6 rows in the segregating generations obtained from hybridization or induced mutation in blackgram as well as in greengram. When all the plants of the infector row show symptoms of MYMV, the test material is scored on a 1-9 scale as described by Shukla (1977; Shukla et al. 1978) for greengram and Singh (1980) for blackgram. No insecticide is sprayed on the breeding material in order not to disturb the population increase of the vector (whitefly-*Bemisia tabaci* Genn.). This method has allowed promising lines of blackgram and greengram resistant to MYMV to develop.

Screening against leaf crinkle virus is done by rubbing the sap at primary leaf stage (Nene 1972). To transfer mosaic mottle virus, Nene (1972) inoculated seedlings mechanically by rubbing the inoculum, prepared in a sodium phosphate buffer of pH 7.6.

Thakur et al. (1977) found infected dried leaves to be both a good source of inoculum for *Cercospora* leaf spot and storable without loss of virulence in a refrigerator. The inoculum was prepared by soaking and squeezing the infected leaves in water. The suspension was filtered through muslin cloth and used for spray inoculations at a concentration of conidia at 500 to 1000/ml on 45 to 50 days old plants.

Infection by powderey mildew is preferably applied by shaking conidia from heavily infected leaves over young seedlings of the test material.

For root infecting pathogens (*Pythium, Rhizoctonia* and *Fusarium*) diseased soil can be built up by continuous sowing of susceptible crops and repeated incorporation of inocula. Screening against soil-borne diseases on such heavily infected fields is the method applied in AVRDC (1976).

Screening for bacterial leaf spot is done by inoculating a suspension (10^6 to 10^7 cells/ml) of *X. phaseoli*, prepared in sterile distilled water and used after 48 hours growth at 30°C. Inoculations are made using rub-inoculation or spraying technique on 25 to 30 days old plants of greengram (Thakur et al. 1977). The pathogen was maintained and multiplied on potato-sugar-peptone-agar and/or yeast-glucose-chalk-agar. Coyne and Schuster (1974) used the multiple needle puncture method for inoculating the foliage and pods of this pathogen in *Phaseolus vulgaris* (L.). The bacterial suspension contained 10^6 to 10^7 cells/ml. Coyne and Schuster (1974) used the same technique for the inoculation of *Pseudomonas phaseolicola* in *Phaseolus vulgaris* (L.).

Sources of Resistance and Varietal Hybridization

Known sources of resistance to different diseases of greengram and blackgram are compiled in Table 1 and 2. Most of the sources are of Indian origin. Lines carrying multiple resistance may be utilized in crossing programmes and the segregating generations may be subjected to screening in

Table 1. Sources of resistance to viral diseases in greengram and blackgram

Mungbean yellow mosaic Virus	References
Greengram	
Moong No. 54	Varma et al. (1973)
P 364-68, P 366-68	Dey and Singh (1974)
15229, ML-1, L 24-2	Gill et al. (1975)
ML-5	Mew et al. (1975)
LM-168, LM-170, LM-214, LM-356, LM-392, LM-404, LM-171, ML-6, 15225, 15227	Virmani et al. (1976)
ML-1. ML-3, ML-5, ML-9	Singh et al. (1977)
Tarai local, L-80, LM 294-1, LM-214	Shukla (1977)
Tarai local	Pandya et al. (1977)
L-24-2-1, 15227	Grewal (1978)
1066, 2779	Legaspi et al. (1978)
Hyb. 12-4, Hyb. 4-3	Mishra et al. (1978)
Vigna sublobata Pantnagar race A	Singh and Ahuja (1977)
L-80, 11/99, 11/395, 16-303-20-3-8	Singh and Sharma (1980, unpublished)
Blackgram	
T-65, T-67	Srivastava et al. (1969)
UPU-1, UPU-2	Nene (1972)
128, 129, 133, 151, 296	Ahmad and Harwood (1973)
Pant U-19, Pant U-26 and Pant U-30	Singh and Singh (1979)
Gwalior, BR-61, 153, NP-21	Singh, Singh and Sharma (1980)
Mosaic mottle virus	
Greengram	
Hyb-45, T-2	Nene (1972)
Blackgram	
T-65, T-67	Srivastava et al. (1969)

Table 2. Sources of resistance to fungal and bacterial diseases in greengram and blackgram

Cercospora leaf spot	References
Greengram	
P-476, P-530, PLM-501	Patel et al. (1972)
Co 1	Singh et al. (1974)
15229	Gill et al. (1975)
LM-157, T-2, ML-5, LM-448, ML-3 ML-4, ML-9, ML-28, ML-29, ML-23	AVRDC (1976)
LM-162, 6008-1, 364-68-1, 546-68-1, 554-1	Grewal (1978)
Gujrat 1, BR 1 ML-9, 24-11-23-3-9-1 CES-2C-1, Suneuna	Singh, and Sharma (1980, unpublished)
Blackgram	
4387, 3529	AVRDC (1976)
Powdery mildew	
Greengram	
ML-163, NP-52, LM-6, LM-2, M-606, LM-156, M-957, C-20139, LM-141, LM-340	AVRDC (1976)
29-13-2	Grewal (1978)
2106, 2773, 2013	Legaspi et al. (1978)
Root and stem rots	
Greengram	
ML-161, ML-5, ML-4, NP-52, LM-8, C35-1 Stab-124, OB 24-1, ML-162	AVRDC (1976)
LM-220, MS-938	Grewal (1978) Vidhyasekaran et al. (1977)
Black gram	
3115	AVRDC (1976)
Bacterial blight	
Greengram	
15229, L 24-2	Gill et al. (1975)
ML-8, ML-10, Jalgaon-781	Chand et al. (1977)

multiple disease nurseries to recover segregants with multiple resistance.

In greengram, the lines 15229, ML-9. ML-3, ML-5 are resistant against both CLS and MYMV. ML-4 and LM-162 are resistant to CLS, root and stem rots and NP-5 to root rots, stem rots and powdery mildew. ML-5 is also resistant to root and stem rots and 15229 to bacterial blight.

In blackgram, T-65 and T-67.are resistant to MYMV and mosaic mottle virus.

Interspecific Hybridization

Wide crosses will increase gene pool available in breeding greengram and blackgram. Crosses between the two species, using the former as the female parent, were made by Sen and Ghosh (1960). The F_1 seeds were small and shrunken, and plants from such seeds were weak and semisterile. Plants from backcross progenies were more vigorous but showed 50 to 70 per cent pollen sterility. Boling and Maltcock (1961) reported 20 per cent seed set in a cross between greengram and blackgram. While *V. radiata* is easily crossable as female to *V. mungo*, the reciprocal cross is not successful. The F_1 hybrid can be backcrossed to *radiata* but not to *mungo* (Jain and Mehra 1978). Major stable genes for *Cercospora* leaf spot resistance are being transferred from blackgram to greengram at AVRDC (1979). Singh and Ahuja (1977) reported two sympatric types, A and B of *V. sublobata*, to be present in the Pantnagar and adjoining *Tarai* areas. The two types were de-

scribed as morphological traits by Arora et al. (1973) and tested for resistance to MYMV and crossibility behaviour by Singh and Ahuja (1977). Crosses between the two types A and B failed. Interspecific crosses between MYMV susceptible varieties of *V. radiata* (T-44, Hybrid-45 and 'Pusa Baisakhi') and *V. sublobata* Pantnagar type A (resistant to MYMV) were made, and segregants with resistance to MYMV were recovered (Singh and Ahuja 1977).

The interspecific cross between greengram and rice bean (*Vigna umbellata*) has been made using the former as female parent and with the ambition to transfer genes for resistance to diseases and pests. The cross proved twice as successful when an immunosuppressant, E-aminocaproic acid (EACA) at a concentration of 100 ppm, was sprayed on the foliage of the seed parent (AVRDC 1976) Baker et al. (1975) reported that the FACA at the rate of 250 ppm was found to be optimum for making crosses including *Vigna* species. The EACA was injected into the internode of maternal plants at the pre-meiotic stage of flower development.

Induced Mutations

Blackgram and greengram are mostly grown on marginal lands and it is possible that the genes for higher productivity could have been lost due to the overriding role of natural selection. Induced mutations may compensate for such losses by creating variability for yield, yield components, plant type, and resistance to disseases and pests.

Dubinin (1964) reported 7.5 to 30 kilored doses as critical for *V. mungo*. Singh and Pandya (1977) studied radiosensitivity in *V. radiata*. The dose levels of 40 to 50 kR were found critical for varieties such as T-44 and ML-26.

A spontaneous mutation for lobed leaf type was observed in greengram by Pokle (1972) and a sterile (Saini et al. 1974) and giant mutant was artificially induced by Bhatt et al. (1972). Morphological and chlorophyll mutations were reported to be induced in blackgram by Jana (1963), Jana and Rao (1974, a, b), Rao and Reddy (1975), Rao et al. (1975), and Rao and Jana (1976). Increased variability within treated populations as compared to control is reported for yield and yield components (Veeraswamy et al. 1973; Dahiya 1973; Rajput 1974; Tikoo and Jain 1974; Shakoor et al. 1978; Singh et al. 1979) and for number of nodules (Rangaswamy et al. 1973; Oblisami et al. 1973). The present author started an experiment on induced mutations in greengram in 1976. The varieties ML-26 and T-44, susceptible to MYMV, were exposed to dose of 10, 20, 30, 40, and 50 kR of gamma-rays (Co^{60}-source). The M_2 and M_3 generations were grown in plant progeny plots. The blackgram cultivar UL-2, highly susceptible to MYMV, was replicated after each 5 rows in M_2 and after each 6 rows in M_3 in 1977 and 1978, respectively. Individual plants were selected in M_2. Plants and/or progenies were selected in M_3. During the visual selection, emphasis was given to higher pods per plant and/or seeds per pod. Plants/progenies superior for pods per plant and/or seeds per pod with or without induced resistance to MYMV were selected. Eleven progenies superior for pods per plant and/or seeds per pod were tested in randomized block design with 3 replications for their yielding ability and resistance to MYMV (Table 3). The gamma-rays exposure increased variability for yield, yield components

Table 3. The performance of mutant (M_4) progenies as compared to the parental check varieties

Variety/dose/ progeny No.	Days of maturity	Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed weight (g)	Yield Kg/ha	MYMV score[a]
ML-26/50/7	77	103.1	25.2	10.1	2.58	1644.0	5.6
ML-26/50/12	76	87.9	28.4	9.5	2.82	1221.5	6.6
ML-26/30/7	78	96.8	29.4	10.0	3.21	1805.5	7.4
ML-26/20/19	71	70.0	25.3	9.0	2.67	1814.0	1.0
ML-26/20/17	75	83.8	23.6	10.1	2.87	1717.6	3.3
ML-26/20/16	75	78.9	23.8	10.0	2.88	1519.1	2.1
ML-26/10/4	75	84.4	27.8	10.1	3.08	1780.0	3.3
ML-26/10/3	79	81.5	29.6	10.1	2.97	1904.7	2.5
T-44/20/1	73	77.0	24.7	9.8	2.37	821.4	7.9
T-44/10/1	71	73.8	31.2	9.3	2.32	697.2	5.6
T-44/20/44	68	62.9	33.0	9.1	2.83	904.2	6.4
T-44 (Check)	74	71.6	25.9	9.0	3.01	762.4	7.1
ML-26 (Check)	80	65.2	24.0	8.5	2.71	1176.3	5.9

Least significant difference at 5 per cent = 436.0 kg/ha. Coefficient of variation = 19.0 per cent

[a] MYMV reaction was scored on 1-9 scale, where, 1 = immune; 3 = resistant; 5 = moderately resistant; 7 = moderately susceptible and 9 = susceptible

Fig. 3. An M_2 mutant plant derived from line ML-26 given 10 kR dose. The pods emerge outside the leaf canopy and the mutant is resistant to MYMV

and MYMV resistance. Shakoor et al. (1977) irradiated 8 varieties of greengram with various doses of gamma-rays. The screening for resistance to MYMV was done in M_3 and 6 recessive mutants resistant to this disease were detected. Some of these were shorter in stature than the parents.

The Genetics of Resistance to Different Diseases

Yield and yield components are negatively correlated with degree of MYMV infection. Path-coefficient analysis shows that infection of greengram by MYMV exerts a high indirect effect on yield via decreased seed weight (Singh et al. 1978). Negative correlation of yield with virus and mildew score is reported by Yohe and Poehlman (1975).

Susceptibility in greengram to MYMV is reported to be dominant over resistance (Shukla 1977; Shukla et al. 1978), in blackgram (Singh 1980) and the same is found for soybeans (Malick 1976; Singh and Malick 1978). In both crops, two recessive genes were found to be responsible for resistance. Tolerance against MYMV in greengram seems, however, only to depend on one recessive gene (Thakur et al. 1977a). Tolerance, seed colour and maturity were found to be independently inherited (Singh and Patel 1977). A digenic recessive inheritance of resistance has also been observed against bean yellow mosaic virus in snapbean as well as in interspecific crosses between *Phaseolus vulgaris* × *P. coccineus* (Bagget 1957; Bagget and Frazier 1957).

The resistance to mosaic mottle virus in greengram is reported to be controlled by a single dominant gene with no maternal effect (AVRDC 1977).

A dominant gene for resistance to CLS in greengram is reported with an independent inheritance in relation to pigmentation (Thakur et al. 1977 a and b). A gene for resistance to CLS is also found in *Vigna unguiculata* (Fery et al. 1975).

The resistance to powdery mildew in greengram is controlled by a single dominant gene (AVRDC 1978).

Young seedlings of some resistant cultivars of greengram show strong hypersensitive reaction to BLS, a symptom at adult stage changed to a few spots on old leaves (Patel et al. 1972). Resistance against BLS first appeared to be monogenic and dominant (Thakur et al. 1977a; Singh and Patel 1977). Race-specificity was, however, soon observed (Thakur et al. 1977c) and all possible crosses were made between the differentiating varieties P-23, P-10875, PLM-95, and I.C.-11303-2. F_1 and F_2 plants from the backcrosses were inoculated with 6 races of the pathogen and the interaction analysed. The results indicated that each resistant differential carried only one gene for resistance, each showing dominance in inheritance and nonoverlapping.

Conclusions and Suggestions

Greengram and blackgram are hosts of a number of diseases which cause serious losses. Of the four viral diseases, MYMV is the most important and is transmitted by whitefly. The fungal disease CLS is a problem in all countries where the two crop species are grown. Powdery mildew is a problem in cold dry weather. *Rhizoctonia* is an important pathogen causing rotting of roots and stem. Mungbean scab (*Elsinoe iwatae*) and anthracnose (*Colletotrichum lindemuthianum*) are localised to Indonesia and the Philippines, respectively, and are there very devastating. Among the bacterial diseases BLS is important.

The natural variability within greengram and blackgram is incompletely explored and much germplasm remains to be collected and catalogued. Such an ambition might even be given priority in a breeding programme.

Grown on marginal lands, there are risks for loss of genes for higher productivity motivating induction of mutations and interspecific hybridization.

The genetic variability available with the breeders should be better explored by arranging field screening nurseries under epiphytotic conditions. Favourable environments for such test are built up by planting susceptible spreaders, by spraying fungal/bacterial suspensions or by growing the material in soil infected by soil-borne diseases. In the case of race-specific host: parasite interaction, field screening ought to be complemented by more thorough analyses in glasshouses under artificial inoculation conditions. It is important that all virulent races are considered and checked against available genes for resistance in order

to understand how to proceed properly in the breeding programme.

It is also important to understand whether such a disease breeding project should proceed entirely analytically and step by step or if it is economically preferable to try to combine the efforts into a multiple disease breeding programme. In the latter case the screening of desirable segregants can either be made for disease or all together.

Acknowledgement

The author is grateful to his graduate students, Mr. S.K. Kundu and Mr. R. Lavania for their help in compiling the literature. He is also grateful to his colleagues, Drs. I.S. Singh and H.H. Ram for going through the manuscript and offering critical suggestions.

Literature

Ahmad, M.; Harwood, R.F. (1973): Studies on a whitefly transmitted yellow mosaic of urdbean (*Phaseolus mungo*). Plant Dis. Rep. 57, 800-802

Ahuja, M.R.; Singh, B. (1977): Induced genetic variability in mungbean through interspecific hybridization. Ind. J. Genet. Plant Breed. 37, 133-136

Arora, R.K.; Chandel, K.P.S.; Joshi, B.S. (1973): Morphological diversity in *Phaseolus sublobatus* Roxb. Curr. Sci. 42, 359

AVRDC (1976): Asian vegetable Research and Development Centre. 1976. Mungbean report for 1975, pp. 35-40. Shanhua, Taiwan, Republic of China

AVRDC (1977): Asian Vegetable Research and Development Centre 1977. Progress report for 1977, pp. 47. Shanhua, Taiwan, Republic of China

AVRDC (1978): Asian Vegetable Research and Development Centre 1978. Mungbean report for 1976, pp. 18. Shanhua, Taiwan, Republic of China

AVRDC (1979): Asian Vegetable Research and Development Centre 1979. Progress report for 1978, pp. 77. Shanhua, Taiwan, Republic of China

Bagget, J.R. (1957): Effects of genetic segregation in *Phaseolus vulgaris* on the symptoms induced by bean yellow mosaic virus. Phytopathology 47, 365-368

Bagget, J.R.; Frazier, W.A. (1957): The inheritance of resistance to bean yellow mosaic virus in *Phaseolus vulgaris*. Proc. Am. Soc. Hortic. Sci. 70, 325-333

Baker, L.R.; Chan, N.C.; Park, H.G. (1975): Effect of an immunosuppressant on an interspecific cross of the genus *Vigna*. Hortic. Sci. 10. 313

Bharti, M.P. (1978): Mungbean in Nepal. First Intl. Mungbean Symp. Proc., Univ. Philippines, 1977, pp. 18-20

Bhatt, B.N.; Kotwal, S.V.; Chandola, R.P. (1972): A giant variant in greengram (*Phaseolus aureus* Roxb.). Curr. Sci. 41, 854-855

Boling, H.S.; Maltlock, R.S. (1961): Mungbean hybridization technique. Agron. J. 53, 54

Chand, J.N.; Yadav, O.P.; Yadav, H.C. (1977): Rection of genetic stocks of mungbean to bacterial blight (*Xanthomones phaseoli*). Indian Phytopathol. 30, 565

Candolle, A. de (1884): Origin of cultivated plants. New York: Haufer Press

Catedral, I.G.; Lantican, R.M. (1978): Mungbean breeding program of UPLB, Philippines. First Intl. Mungbean Symp. Proc., Univ. Philippines, 1977, pp. 225-227

Coyne, D.P.; Schuster, M.L. (1974): Breeding and genetic studies of tolerance to several bean (*Phaseolus vulgaris* L.) bacterial pathogens, Euphytica 23, 651-656.

Dahiya, B.S. (1973): Improvement of mungbean through induced mutations. Indian J. Genet. Plant Breed. 33, 460-468

De Deepesh, N. (1978): Origin, evolution and distribution of *Cajanus* and *Phaseolus*. Western ghats as microcentre. Indian J. Genet. Plant Breed. 36, 141-142

Dey, S.K.; Singh, D.R. (1974): Resistance list of mung (*Phaseolus aureus* L.) against yellow mosaic in Uttar Pradesh. Indian J. Farm. Sci. 1, 113

Dhingra, K.L. (1975): Transmission of urdbean leaf crinkle virus by two aphid species. Indian Phytopathol. 28, 80-82

Duangploy, S. (1978): Breeding mungbean for Thailand conditions. First Intl. Mungbean Symp. Proc. Univ. Philippines, 1977, pp. 228-229

Dubinin, N.P. (1964): Problems of radiation genetics. Edinburgh, London: Oliver Boyd

Evans, A.M. (1975): Species hybridization in the genus *Vigna*. Proc., IITA collaborators Meeting on grain leg. Improv., pp. 31-34. IITA, Ibadan, Nigeria

Fang, C.T.; Chen, H.Y.; Chu, C.L. (1964): A comparative study of the species of the genus *Xanthomonas* from leguminous plants. Acta Phytopathol. Sinica 7, 21-31

Fery, R.L.; Dukes, P.D.; Cuthbert, F.P. Jr. (1975): Resistance in the southern pea (*Vigna unguiculata* (L.) Walp) to *Cercospora* leaf spot. Sci. 10, 313

Gill, K.S.; Sandhu, T.S.; Singh, K.; Brar, J.S. (1975): Evaluation of mungbean (*Vigna radiata* L. Wilczek), Germplasm. Crop Improvement 2, 99-104

Crewal, J.S. (1978): Diseases of mungbean in India. First Intl. Mungbean Symp. Proc., Univ. Philippines, 1977, pp. 165-168

Hepper, F.N. (1956): New raxa of *Papilionaceae* from W. tropical Africa. Kew Bull. 11, 128

Ilag, L.L. (1978): Fungal diseases of mungbean in the Philippines. First Intl. Mungbean Symp. Proc., Univ. Philippines, 1977, pp. 154-156

Islam, M.A. (1978): Mungbean cultivation in Bangladesh. First Intl. Mungbean Symp. Proc. Univ. Philippines, 1977 pp. 21-23

Jain, H.K.; Mehra, K.L. (1978): Evaluation, adaption, relationship and use of the species of *Vigna* cultivated in Asia. Paper presented in the Int. Legume Conference, Roy. Bot. Gardens, Kew, July 24 -Aug. 4

Jana, M.K. (1963): X-ray induced mutations of *Phaseolus mungo* L. Chlorophyll mutations. Caryologia 16, 685-692

Jana, M.K.; Rao, S.A. (1974a): Anthocyaninless mutant of blackgram (*Phaseolus mungo*). Mutation Breed. Newsl. 3, 11

Jana, M.K.; Rao, S.A. (1974b): Inheritance of pigmentation in blackgram. Indian J. Genet. Plant Breed. 34, 36-40

Johnson, A. (1970): A supplement to a host list of plant diseases in Malaya. C.M.I. Mycol. Papers No. 77

Kolte, S.J.; Nene, Y.L. (1972): Studies on symptoms and mode of transmission of the leaf crinkle virus of urdbean (*Phaseolus mungo*). Indian Phytopathol. 25, 401-404

Kolte, S.J.; Nene, Y.L. (1975): Host range and properties of urdbean leaf crinkle virus. Indian Phytopathol. 28, 430-431

Legaspi, B.M.; Catipon, E.M.; Hubell, J.N. (1978): AVRDC Philippine outreach program, Mungbean studies. First Intl. Mungbean Symp. Proc., Univ. Philippines, 1977, pp. 220-223

Malick, A.S. (1976): Inheritance of resistance to yellow mosaic in soybean (*Glycine max* (L.) Merrill). M. Sc. thesis, G.B. Pant Univ. Agric. Tech., Pantnagar, India

Marechal, R. (1975): Studies in Phaseolinae. Kew Bull. 11, 35-37

Mew, I.P.; Wang, T.C.; Mew, T.W. (1975): Inoculum production of mungbean variaties for resistance to *Cercospora canescens*. Plant Dis. Rep. 29, 397-401

Mishra, R.C.; Tripathy, D.; Sahu, R.C. (1978): YMV resistant mungbean for summer cultivation. Indian J. Genet. Plant Breed. 38, 103-105

Nair, N.G. (1971): Studies on the yellow mosaic of urdbean caused by mungbean yellow mosaic virus Ph.D. thesis, U.P. Agric. Univ., Pantnagar, India

Nair, N.G.; Nene, Y.L.; Naresh, J.S. (1974): Reaction of certain urdbean varieties to yellow mosaic virus of mungbean. Indian Phytopathol. 27, 256-257

Nalampang, A. (1978): Mungbean production in Thailand. First Intl. Mungbean Symp. Proc., pp. 12-14. Univ. Philippines, 1977

Narayanaswamy, P.; Jaganathan, T. (1975): Effect of blackgram leaf crinkle virus infection on seed set and distribution of virus in the seeds. Madras Agric. J. 62, 151-154

Nariani, T.K. (1960): Yellow mosaic of mung (*Phaseolus aureus* L.) Indian Phytopathol. 13, 24-29

Nariani, T.K.; Kandaswami, T.K. (1961): Mosaic disease of cowpea (*Vigna sinensis* Savi). Indian Phytopathol. 14, 27

Nene, Y.L. (1968): Annual report (No. 1) project, FG-In-358, U.P. Agric. Univ., India

Nene, Y.L. (1969): A survey of the viral diseases of pulse crops in Uttar Pradesh. IInd Annual report, pp. 1-39. FG-In-358, U.P. Agric. Univ., India

Nene, Y.L. (1970): A survey of the viral diseases of pulse crops in Uttar Pradesh IIIrd Annual report, pp. 1-26. FG-In-358, U.P. Agric. Univ., India

Nene, Y.L. (1972): A survey of viral diseases of pulse crops in Uttar Pradesh, G.B. Pant Univ. Agric. Tech., Pantnagar, Res. Bull. 4

Nene, Y.L. (1973): Viral diseases of some warm weather pulse crops in India. Plant Dis. Rep. 5, 463-467

Nene, Y.L.; Srivastava, S.K.; Naresh, J.S. (1972): Evaluation of urdbean (*Phaseolus mungo* L.) and mungbean (*Phaseolus aureus* L.) germplasms and cultivars against yellow mosaic virus. Indian J. Agric. Sci. 42, 251-254

Oblisami, G.; Ramaswamy, N.M.; Purushottaman, D.; Rangaswami, G. (1973): Preliminary studies on the rhizobial nodulation of induced mutants of blackgram. Madras Agric. J. 60, 259-261

Pandya, B.P.; Singh, D.P.; Sharma, B.L. (1977): Screening of mungbean (*Vigna radiata* (L.) Wilczek) germplasm for field resistance to yellow mosaic virus. Trop. Grain Legume Bull. 7, 13-14

Park, H.G.; Yang, C.N. (1978): The mungbean breeding programme at the Asian Vegetable Research and Development Centre. First Intl. Symp. Proc. Univ. Philippines, 1977, pp. 214-216

Patel, P.N.; Jindal, J.K. (1972): Bacterial leaf spot and halo blight diseases of mungbean (*Phaseolus aureus*) and other legumes in India. Indian Phytopathol. 25, 517-525

Patel, P.N.; Jindal, J.K.; Singh, D. (1972): Studies on resistance in crops to bacterial diseases in India. Resistance in mungbean (*Phaseolus aureus*) to *Xanthomonas phaseoli*. Indian Phytopathol. 25, 526-529

Pokle, Y.S. (1972): Spontaneous mutation in mung (*Phaseolus aureus* Roxb.). Sci. Cult. 38, 420

Quebral, F.C. (1978): Powdery mildew and *Cercospora* leaf spot of mungbean in the Philippines. First Intl. Mungbean Symp. Proc. Univ. Philippines, 1977, pp. 147-148

Rachie, K.O.; Roberts, L.M. (1974): Grain legumes of lowland tropics. Adv. Agron. 26, 2-118

Rajput, M.A. (1974): Increased variability in the M_2 of gamma-irradiated mungbeans (*Phaseolus aureus* Roxb.). Radiat. Bot. 14, 85-89

Rangaswami, G.; Gowda, S. (1963): On some bacterial diseases of ornamentals and vegetables in Madras state. Indian Phytopathol. 16, 74-85

Rangaswamy, S.R.S.; Oblisami, G.; Krishnaswamy, S. (1973): Nodulation and productivity in the induced mutants of greengram by gamma-rays. Madras Agric. J. 60, 359-361

Rao, S.A.; Rao, S.P.; Jana, M.K. (1975): New plant type in blackgram. Curr. Sci. 44, 679-680

Rao, S.A.; Reddy, M. (1975): Crumpled petal mutants in blackgram and cowpea. Indian J. Genet. Plant Breed. 35, 391-394

Rao, S.A.; Jana, M.K. (1976): Leaf mutations induced in blackgram by X-rays and EMS. Environ. Expt. Bot. 16, 151-154

Rath, G.C.; Grewal, J.S. (1973): A note on *Cercospora* leaf spot of *Phaseolus aureus*. Indian J. Mycol. Plant Pathol. 3, 204-207

Rathi, Y.P.S.; Nene, Y.L. (1974): The additional hosts of mungbean yellow mosaic virus. Indian Phytopathol. 27, 429-430

Saini, R.G.; Minocha, J.L.; Singh, A. (1974): Sterile mutants in *Phaseolus aureus*. Sci. Cult. 40, 37-38

Saksena, H.K.; Dwivedi, R.P. (1974): Occurrence of web blight by *Thanatephorus cucumeris* on mungbean. Indian. J. Farm. Sci. 2, 100

Sen, N.K.; Ghosh, A.K. (1960): Interspecific hybridization between *P. aureus* and *P. mungo*. Bull. Bot. Soc. Bengal 14, 1-4

Shahare, K.C.; Raychaudhary, S.P. (1963): Mosaic disease of urid (*Phaseolus mungo* L.) Indian Phytopathol. 16, 316-318

Shakoor, A.; Haq, M.A.; Sadiq, M.; Sarwar, G. (1977): Induction of resistance to yellow mosaic virus in mungbean through induced mutations, Induced mutations against plant diseases, pp. 293-302. Symp. Proc. IAEA Vienna, 1977

Shukla, G.P. (1977): Studies on the inheritance of resistance to mungbean yellow mosaic virus in greengram (*Vigna radiata* (L.) Wilczek). Ph.D. thesis, G.B. Pant Univ. of Agric. and Tech., Pantnagar, India

Shukla, G.P.; Pandya, B.P.; Singh, D.P. (1978): Inheritance of resistance to yellow mosaic in mungbean. Indian J. Genet. Plant Breed. 38, 357-360

Singh, B.B.; Malick, A.S. (1978): Inheritance of yellow mosaic in soybean. Indian J. Genet., Plant Breed. 38, 258-261

Singh, B.V.; Ahuja, M.R. (1977): *Phaseolus sublobatus* Roxb. A source of resistance to yellow mosaic virus for cultivated mung. Indian J. Genet. Plant Breed. 37, 130-132

Singh, B.V.; Singh, D.P.; Pandya, B.P. (1978): Association of yield and yield components and the component analysis in mungbean (*Vigna radiata* (L.) Wilczek). Pantnagar J. Res. 3, 8-11

Singh, D.; Patel, P.N. (1977): Studies on resistance in crops to bacterial diseases in India. Investigation on inheritance of resistance to bacterial leaf spot and yellow mosaic diseases and linkage, if any, with other characters in mungbean (*Vigna radiata*). Indian Phytopathol. 30, 202-206

Singh, D.P. (1980): Inheritance of resistance to yellow mosaic virus in blackgram (*Vigna mungo* (L.) Hepper). Theor. Appl. Genet. 57, 233-235

Singh, D.P.; Pandya, B.P. (1977): Studies on radio-sensitivity in mungbean (*Vigna radiata* (L.) Wilczek). Trop. Grain Legume Bull. 9, 25-27

Singh, D.P.; Singh, H.P.; Sharma, B.L. (1980): Evaluation of blackgram (*Vigna mungo* (L.) Hepper) germplasm. Pantnagar J. Res. (in press)

Singh, D.P.; Vaidya, K.R.; Bhatt, D.D. (1979): Gamma-ray induced variability for flowering and cholorophyll mutations in greengram (*Vigna radiata* (Linn.) Wilczek). Indian J. Agric. Sci. 49, 835-838

Singh, H.B.; Joshi, B.S.; Chandel, K.P.S.A.; Pant, K.C.; Saxena, R.K. (1974): Genetic diversity in some Asiatic *Phaseolus* species and its conservation (in) Breeding Research in Asia and Oceania. Indian J. Genet. Plant Breed. 34 (A), 52-57

Singh, H.B.; Arora, R.K.; Hardas, M.W. (1975): Untapped plant resources. Proc. Indian Nat. Sci. Acad. B 41, 194-203

Singh, H.P.; Singh, D.P. (1979): Recent advances in urdbean and mungbean production. Ind. Farming, 24(3), 18-20

Singh, K.B.; Sandhu, J.S.; Malhotra, R.S.; Brar, J.S. (1977): ML-5 A new moong. Indian Farming, 7-8

Srivastava, K.M.; Verma, G.S.; Verma, H.N. (1969): A mosaic disease of blackgram (*Phaseolus mungo*) Sci. Cult. 35, 475-476

Thakur, R.P.; Patel, P.N.; Verma, J.P. (1977a): Genetical relationships between reactions to bacterial leaf spot, yellow mosaic and *Cercospora* leaf spot diseases in mungbean (*Vigna radiata*). Euphytica 26, 765-774

Thakur, R.P.; Patel, P.N.; Verma, J.P. (1977b): Independent assortment of pigmentation and resistance to *Cercospora* leaf spot in mungbean. Indian Phytopathol. 30, 264-365

Thakur, R.P.; Patel, P.N.; Verma, J.P. (1977c): Studies on resistance in crops by bacterial diseases in India. Genetic make-up of mungbean differentials of the races of bacterial leaf pathogen, *Xanthomonas phaseoli* Indian Phytopathol. 30, 217-221

Tikoo, J.L.; Jain, H.K. (1974): Mutation studies in mungbean. Mutation Breed. Newsl. 3, 10-11

Varma, J.P.; Kadian, O.P.; Singh, J.P. (1973): Occurrence and incidence of virus diseases of mung and urid in Haryana. Indian Phytopathol. 26, 592-594

Vavilov, N.I. (1926): Origin, variation, immunity of cultivated plants (Translated by K. Starr Chester). Chron. Bot. 13, 1-364 (1949-50)

Veeraswamy, R.; Rathnaswamy, R.; Palaniswamy, G.A. (1973): Genetic variability in some quantitative characters of *Phaseolus aureus* Roxb. Madras Agric. J. 60, 1320-1322

Vidhyasekaran, P.; Arjunan, G.; Ranganathan, K. (1977): Resistance in some mung varieties against root rot. Indian Phytopathol. 30, 404

Virmani, S.S.; Singh, K.B.; Singh, K. (1976): Note on the screening of greengram germplasm against yellow mosaic virus disease in India. Indian J. Agric. Sci. 46, 243-245

Vohra, K. (1976): Effect of mungbean yellow mosaic virus on seed quantity and quality of urdbean (*Phaseolus mungo* L.). M. Sc. Thesis, G.B. Pant. Univ. Agric. Tech., Pantnagar, India

Welles, C.C. (1924): Studies on the leaf spot of *Phaseolus aureus* new to the Philippines Islands. Phytopathology 14, 351-358

Wilczek, R. (1954): *Vigna*. Flore du Congo Belge. 6, 343-393

Williams, F.J.; Grewal, J.S.; Amin, K.S. (1968): Serious and new diseases of pulse crops in India in 1966. Plant Dis. Rep. 52, 300-304

Yohe, J.M.; Poehlman, J.M. (1975): Regressions, correlations and combining ability in mungbeans (*Vigna radiata* (L.) Wilczek). Trop. Agric. 52, 343-352

Zukovaskij, P.M. (1962): Cultivated plants and their wild relatives. Commonwealth Agric. Bureau: London

Received June 6, 1980
Communicated by J. Mac Key

Dr. D.P. Singh
Department of Plant Breeding
Govind Ballabh Pant University
of Agriculture and Technology
Pantnagar-263145 (India)