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Abiotic and biotic stresses and their effect on *Vigna radiata* L.

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Abstract
Mungbean (*Vigna radiata* L.), popularly known as green gram is a major pulse crop and cultivated worldwide on about 8 percent of the global cultivated area. Its production and productivity is severely affected by certain biotic and abiotic factors. Various plant breeders mainly concentrate on limiting the effects caused by abiotic and biotic stresses and understanding the phenomenon that act against in response to these stresses, to improve the yield and quality of the crops. Certain molecular and biochemical mechanism that are related with stress response provide information about the breeding programs that can be used by plant breeders for developing high yielding and resistance varieties. However, there are certain constraints that hinder the exact and error-free spotting of resistance sources. To overcome this limitation, researches have been conducted to ascertain the alterations in the expression of numerous defense related mechanisms in resistant and susceptible green gram varieties in response to various stress. This manuscript is a review of such research programmes that aimed at developing novel cultivars in *Vigna radiata* that show better tolerance to various biotic and abiotic stress.

Keywords: Defense-mechanisms, resistant sources, stress, tolerance, *Vigna radiata*

1. Introduction

The essential and inexpensive source of nutrients and proteins for human are commonly found in legume crops (Foyer *et al*., 2016) [17]. Leguminous plants also boost the fertility of soil by fixing atmospheric nitrogen (Snapp *et al*., 2010) [74]. Green gram (*Vigna radiata*) is a major cash crop and broadly cultivated in Asia. Mungbean is having relatively small genome size (579 Mb) with chromosome number (2n=22) (Parida *et al*., 1990; Kang *et al*., 2014) [55, 23]. Mungbean is native to Indo-Burma or India region and is the third most important crop after chickpea and pigeonpea. For mungbean, the primary center of genetic diversity is believed to be central Asian region. It is a self-pollinated and short-term crop, which belongs to family fabaceae and genus *Vigna* (Kumar and Kumar, 2014) [33]. It is also named as greengram, mashbean, greensoy, greenbean and goldengram (Markam *et al.*, 2018) [44]. It grows in area with high temperature (27 to 30 °C) with moderate rainfall (60 to 75 cm) and low humidity. It is rich in various vitamins (riboflavin, thiamine, niacin, vitamin C and vitamin K) and minerals (potassium, magnesium, iron, calcium, manganese and zinc) & protein and can be consumed in number of ways *viz.*, beans, paste, flour or as sprouts (Itoh *et al*., 2006) [21].

The productivity of the crop is declining due to exterior environment that act on the plant and negatively affect the growth, cellular metabolism and yield potential of the plant, which is referred as stress. Numerous diseases in green gram *viz*., powdery mildew, yellow mosaic, anthracnose, leaf spot, rust, leaf crinkle, dry root rot and tan spot that is caused by various biotic factors such as fungi, virus, whitefly, stem fly, pod borer and aphids (Pandey *et al*., 2018; Singh *et al.*, 2000) [52]. In addition, abiotic factors like water logging, drought, extreme temperature, salinity and poor cultivation practices also leads to reduction in productivity (Pratap *et al.*, 2019; Rao *et al*., 2016) [59]. Among these drought is a major abiotic factor in mungbean, effect of which has been assessed using various parameters *viz.* proline concentration, leaf area index and antioxidant enzymatic activities (Dutta and Bera, 2008; Ahmad *et al*., 2015) [14]. Several shielding mechanisms act in opposition to biotic and abiotic stresses for protection of the plant. Mainly, the high concentration of salts and hyperosmotic stress is accountable for such reduction of productivity in green gram. In reaction to various biotic and abiotic stress plant expresses certain genes like antimicrobial genes, pathogenesis related genes, QTL related with tolerance to abiotic stress, etc. that are involved in plant defense mechanism. These are genes which express themselves in response with plant defense mechanism against certain biotic and abiotic stress (Liu and Ekramoddoullah 2006) [36].

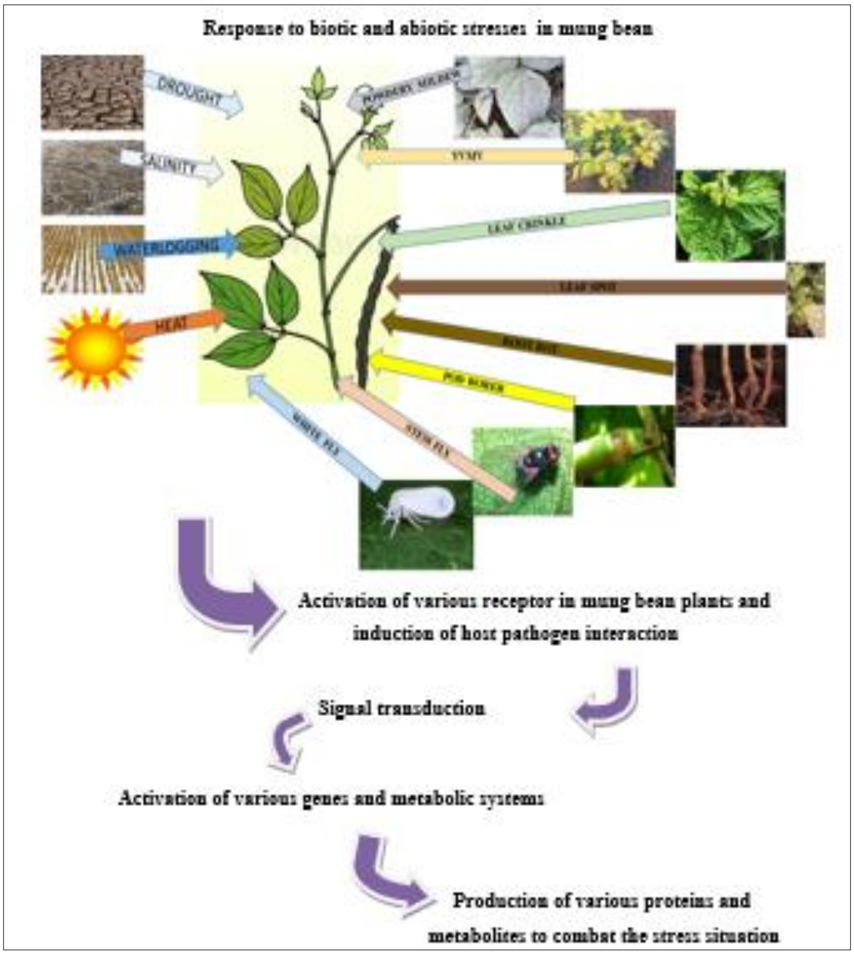

Fig 1: Response to biotic and abiotic stresses in mung bean

Moreover, intracellular proteins for instance, PR10 proteins, which can be found in dicotyledonous and monocotyledonous plant species (Walter *et al*. 1990) [84] have numerous activities including RNAse activity, which is vital for protection of plant at odds with pathogenic infections (Liu and Ekramoddoullah 2006) [36]. Apart of it some enzymes like superoxide dismutase, catalases, peroxidases are involved in plants to hinder the toxicity of Reactive Oxygen Species (ROS) by anti-oxidation (Foyer *et al*., 1994). Reactive oxygen species protects the plants by acting against the pathogen and also act as secondary messengers for the activation of various defensive genes (Mehdy 1994) [46].

2. Abiotic stress in mungbean

Plants make use of several resources from environment for growth and development such as water, light, nutrient and minerals. The modification of environment has a considerable influence on the growth and yield of the plant thus causing large scale dropping in farming globally (Arun and Venkateswarlu, 2011; Ye *et al*., 2017) [5]. Plant-environment interaction gets disturbed due to variation in the weather and also due to cultivation practices. The tolerance mechanism stimulates various stress-regulated gene which help them to combat against certain abiotic stresses. The plants behave differently in response to the external environment, which help them to adjust according to the specific harsh environmental conditions like Moisture stress, salinity stress, heat stress etc. A number of genotypes have been screened & evaluated as source of tolerance to various abiotic stresses which have been listed in table 1.

2.1 Effect of drought stress

The elevation of drought stress causes speedy loss in leaf chlorophyll content. The rising time span of drought stress results in downslide of chlorophyll-a and chlorophyll-b. The drought stress tolerance in green gram can be signaled by Chlorophyll Stability Index (CSI). In addition, the increased chlorophyll stability index assists crops to hold out against drought conditions resulting in maintaining chlorophyll content by producing more dry matter and increase yield (Chaves M.M., *et al*., 2002) [11]. Moreover, Proline content is a signal that indicates drought stress tolerance of plants. Proline content inclines during the period of drought stress and decline during the restoration interval. Osmotic stability in plant cells can be sustained by collection of proline when plants are subjected to water shortage. The studies show that the plant suffering from drought stress has reported the added accumulation of proline in leaf tissues (Sundaresan S and Sudhakaran P.R 1995) [75]. The reduction in activity of proline dehydrogenase may have the more accumulation of proline in plants during the period of drought stresses. Plant growth in terms of height and leaf area is also adversely affected due to the drought stress. The reduction in plant growth can be caused by the loss of turgor pressure in cells due to this cell wall expansion is terminated thus suppressing the linear growth of shoots. Leaf area measurement shows the reduction in leaf area is observed in plants that are subjected to water deficit than the plants growing under normal environmental conditions (Koleyoreas 1958) [26]. Although, the plants subjected to water stress if re-watered confers an increase in leaf size. This mechanism, reduce the leaf area eventually causing the less water loss from the leaves by the process of transpiration (Karadenir *et al*., 2012; Avramova *et al*., 2015; Larkanthod *et al*., 2018) [24]. Initially, the plants show reduced cell division and then it results in reduced cell number which further causes inhibition of cell elongation. Due to this stability of membrane in plants get reduced (Premachandra G.S., *et al* 1992) [60].

2.2 Effect of salinity stress

The immoderate concentration of the salt affects the growth of crop in numerous ways. It brings down the germination rate of seed, root growth and lengthening of shoots is negatively affected. Excessive NaCl (Sodium Chloride) level also affect the biomass and eventually reduce the yield of the crop (Promila and Kumar, 2000; Rabie, 2005; Ahmed, 2009) [61]. Development of salt tolerant variety in mungbean has not made much advancement because of the multivariate responses. However, Bari Mung-4 variety of mungbean exhibit good performance at high concentration of salt (Naher and Alam, 2010) [50].

2.3 Effect of water logging stress

Water logging is the condition in which soil gets saturated with water and it hinder the entry of air resulting in anaerobic conditions. This can change the amount of nutrients supply for plants which is required for growth and development. Water logging conditions can be caused due to excessive rainfall in which roots get totally or partially submerged in water and it blocks the supply of oxygen (Ahmed *et al*., 2013) [2]. Water logging condition in the mungbean affects the seedling germination and its emergence (Bailey- Serres and Voesenek, 2008; Toker and Mutlu, 2011) [7, 79]. During the stage of pod ripening if water logging condition emerges it leads to untimely germination of seeds. In response to water logging stress, the formation of aerenchyma assists plant to combat water logging condition. In addition to this anti-oxidant defense mechanism also get stimulated to protect the plant against excess water sub-mergence (Pan *et al.,* 2021) [51].

Table 1: Tolerant/resistant sources of mungbean against abiotic stresses

S. No.	Abiotic stresses	Source of tolerance	Country	Reference
1.	Drought	VC 1163 D, VC 2570A, VC 2754 A and VC 2768 A	Taiwan	Fernandez and Shanmugasundaram (1988) [16]
2.	Drought	ML 267	India	Swathi *et al*. (2017)
3.	Drought	K-851	India	Dutta and Bera (2008) [14], Dutta *et al*. (2016) [15]
4.	Drought	V-1281, V-2013 and V-3372	Taiwan	AVRDC (1979) [6]
5.	Drought	TCR 20	India	Tripathy *et al*. (2016) [80]
6.	Drought	SML-1411, SML-1136	India	Kaur *et al*. (2017) [28]
7.	Drought	VC 2917 (seedling stage)	China	Wang *et al*. (2014, 2015) [86]
8.	Drought (maintaining cooler canopy traits)	VC-6173-C, IC-325770, ML 2082	India	Raina *et al*. (2016) [62]
9.	Drought & Flooding	V 1381 and VC 2778	China	He *et al*.(1988) [20]
10.	Salt	NM 19-19	Pakistan	Shakeel and Mansoor (2012) [68]
11.	Salt	S72, H45, No. 525, Madira and RS-4	India	Maliwal and Paliwal (1982) [39]
12.	Salt	TCR86, PLM380, PLM562, WGG37, IC615, PLM891, IC2056, IC10492, PLM32, K851, and BB92R	India	Sehrawat *et al*. (2014) [67]
13.	Salt	BARI Mung-4	Bangladesh	Naher and Alam (2010) [50]
14.	Salt	T-44	India	Misra and Gupta (2006) [47]
15.	Salt	EC 693357, 58, 66, 71 and ML 1299	India	Manasa *et al*. (2017) [40]
16.	Water logging	V 1968, V 2984, V 3092 and V 3372	Taiwan	AVRDC (1979) [6]

3. Analysis of gene expression of phospholipase C in response to abiotic stresses

In eukaryotes cells, phophatidylinositol (PtdIns) is a significant phospholipid. The phosphoinositide (PI) signaling pathway has been implicated in plant growth and development in numerous studies. The phospholipase C (PLC) enzyme is thought to play an important function in the PI pathway. In response to drought and salt stress, the expression of VrPLC was rapidly stimulated in an abscisic acid-independent manner. In leaf tissue, PLC expression was found to be up-regulated by SA (salicylic acid) and down-regulated by wound. However, no significant differences in PLC expression were detected in plants which are exposed to high temperature or H_2O_2. In green gram, there is a strong link/relationship between PLC expression and stress responses. The plant has different defense mechanisms in response to certain stresses to protect them. These physiological responses have been studied under various experiments. One of these is the activation of PLC (Phospholipase C) in reaction to environment stress factors. This enzyme involves in signal transduction pathway helps the plants to modify themselves according to the changes occurring in the environment. In low temperature conditions, the expression of phospholipase C rises gradually in green gram and the evidence shows that the expression of PLS is decreased due to wounds in plants (Gnanaraj *et al*., 2015) [18].

Plant phosphoinositide-specific phospholipases C (PI-PLCs) are involved in a number of important plant activities related to development and stress. The transcriptional and post-transcriptional expression patterns of TaPLC1 are investigated under drought and severe salinity stress. A similar study was done in wheat in which TaPLC1 mRNA is found in all of the wheat organs studied. Seedling development was decreased by U73122 and edelfosine, a PLC inhibitor, and seedling sensitivity to drought and high salinity stress was increased. Though TaPLC1 expression is lowest in wheat seedlings, it is highly upregulated under stressful situations (Zhang *et al.*, 2014) [89].

4. Biotic stress in mungbean

The biotic stress is a damage that is caused by living organism particularly by virus, bacteria, fungus and insect-Pests. Mungbean yellow mosaic disease (MYMD), which is viral disease, is transmitted by whiteflies and considered as a deadly disease in mungbean. Thus it has captured attention of a number of researchers who have reported some of the noble genotypes (table 2) that confer resistance to yellow vein mosaic virus(YVMV). It has been reported that resistance gene present in mung bean is governed by single recessive gene in variety NM92 (Khattak *et al*., 2009).

Table 2: Resistant sources of mungbean against mungbean yellow mosaic disease

Genotype(S)	Resistant level*	Country	Reference
ML-881, UPM-98,	HR		Yadav and Dahiya (2004) [83]
ML1628	T		
VRMG(g)1, LM 235 (GY), K 851, T 44, Nelambur, Sona Moong, AVRDC 1785/5, LM 150, Madura moong, TNAU 26, WBM 202 (GY), KM 2, TARM 22, HUM 1, LGG 429/1, TARM2/2, TARM2/1, NM 94, Bari mung 2	R	India	Pandiyan *et al.* (2007) [53]
ML267, LGG407	R	India	Panduranga *et al.* (2011) [54]
ML-5, ML 405, ML 408, ML 337, MUM 2, VGG3 45, Pusa 8773	R	India	Patel and Srivastava (1990) [57]
ML-818	R	India	Paul *et al.* (2013) [58]
ML-9	MR		
GG-89 and GG-39, R: TM-98-50, TM-97-55, Co-5	I	India	Salam *et al.* (2009) [64]

*(T, Tolerant; I, Immune; HR, Highly resistant; R, Resistant; MR, Moderately resistant).

Cercospora leaf blight is a major fungal disease that occurs in mung bean. It has been described that a single dominant gene controls the resistance to CLS (Lee, 1980) [37]. Bacterial diseases are mainly seed-borne. It has been reported the bacterial leaf blight resistance gene is governed by single dominant gene (Thakur *et al*., 1977) [78]. A number of resistance sources against various diseases in mungbean have been reported and are present in table 3.

Table 3: Resistant genotypes of mungbean against fungal diseases

Diseases	Genotype(s)	Resistant level*	Country	Reference
Anthracnose	ML1194, ML1486, ML1464and ML1349	R	India	Kaur *et al.* (2011) [27]
Cercospora leaf spot (CLS)	V1471, V4718, V5036, V2757 and V2773	R	Taiwan	Hartman *et al.* (1993) [19]
	M5-22 and M5-25	R	Thailand	Wongpiyasatid *et al.* (1999) [88]
	ML5, 453, 443, 515, 688, 610, 613, 682, 746, 611, 735, 728, 713, 759 and 769	R	India	Singh *et al.* (2004) [71]
	PANT M3, PUSA 105, PANT M103, PANT M2, ML 561, ML 347, ML 613, ML 173, PDM 11 and PANT M4	R	India	Marappa (2008) [43]
	ML1194, ML1486, ML1349 and ML1464	R	India	Kaur *et al.* (2011) [27]
	GM-03-03, GM-02-13 and GM-02-08	R	India	Yadav *et al.* (2014b) [82]
	AKM 9910, ML 1299, IPM 02-5, and SML 668	R	India	Akhtar *et al.* (2014) [4]
	ML-5, HUM-9, ML-4, HUM-4, SM-9-124, HUM-1, LGG-450, and SM-9-107	R	India	Singh and Singh (2014) [73]
	KMP-13	MR	India	Bhaskar (2017) [8]
	BRM-188, Basanti, PDM-11, NM-2, 98-cmg-003, NM-1, NM-98, 98cmg-018, C2/94-4-42, VC3960-88, BARIMung-2 and CO-3	HR	Pakistan	Iqbal *et al.* (2004) [22]
Powdery mildew	C1-37-23, C1-28-20, C1-34-23, C1-32-22, C1-38-27, C1-44-31, C1-236-152, C1-41-28, C1-246-159, C1-175-111, C1-275-177	HR	India	Kumar *et al.* (2017) [34]
	HUM 1, Pusa 572, GS 33-5, COGG 936, GS 21-5, AKM 99-4, MH 96-1, TMB 47, ML 1299, MH 530, KGS 83and MH 429	HR	India	Akhtar *et al.* (2014) [4]
	BPMR-145, TARM-18, Vaibhav, Phule M-2002-17, Phule M-2001-5, Phule M-2001-3, Phule M-2003-3 and Phule M-2002-13	R	India	Mandhare and Suryawanshi (2008) [41]
	LGG-460	R	India	Yadav *et al.* (2014a) [81]

*HR, Highly resistant; R, Resistant; MR, Moderately resistant; adopted from Pandey *et al.* (2018) [52].

Insect-pest like pod borer, bruchids, thrips and stem fly also causes major losses to yield (Swaminathan *et al*., 2012) [76]. The International Centre for Tropical Agriculture (CIAT) recognized resistance genes to stem fly. For example, G02005, G02472, G05253 and G05576 are extremely resistant against stem fly (Talekar 1990; Abate *et al*, 1995) [77]. These genotypes have been extensively used in breeding programs to develop the varieties which are resistant against stem fly. White fly, *Bemisia tabaci* can infect the crop by transmitting mungbean yellow mosaic disease (MYMD). It can harm the crop by directly feeding on it and secreting the honey dew that forms black sooty mold. It can cause the yield loss between 20 to 70% in mungbean (Marimuthu *et al*., 1981; Chhabra and Kooner, 1998; Mansoor-Ul-Hassan *et al*., 1998**)** [45, 12, 42]. Mungbean gets infected by thrips during seedling as well as flowering stages. It affects the growth of seedling and in some cases seedling fails to emerge. At the time of flowering, thrips feed on flower causing flower drop and hindrance of pod formation. The yellowing of plants can be caused by cowpea aphid, *Aphis craccivora* which infest the plant by sucking the cell sap. A number of resistant sources against various insect pest has been reported in mungbean (table 4) which can be used in developing insect resistance cultivar.

Table 4: Resistant sources of mungbean against insect pests

Insect pest	Genotype(s)	Resistance level*	Country	Reference
Whitefly (*Bemisia tabaci*)	ML 1, ML 6, ML 7, P 290, P 292, P 131, P 293, P 325, P 364, 11,148	MR	India	Kooner *et al*. (1997) [31]
	ML 1265, ML 1229	R	India	Kooner and Cheema (2007) [32]
	NM 92, NM 98	MR	Pakistan	Khattak *et al*. (2004) [30]
	99.CMG-059, NM 2003-06, NM. 2003-24, NM. 2003-26, NCM. 258, PDM-54	MR	Pakistan	Shad *et al*. (2006) [69]
	VBN 2, CO 8, VGG10-002	MR	India	Sekar and Nalini (2017) [66]
	NM 04-2-38, NM 10-12-1, NM 46-5-2- 21, NM 013, NM 0183, NM 04-1-11, NM 15-11	MR	Pakistan	Akhtar *et al*. (2011) [3]
	MH 3153, NM-92, NM-2006, Azri 2006, NM-121	MR	Pakistan	Nadeem *et al*. (2014) [49], Muhammad *et al*. (2018) [48]
	PKV Green Gold	R	India	Bhople *et al*. (2017) [9]
	Bari Mung-6	R	Bangladesh	Abdullah-Al-Rahad *et al*. (2018) [1]
	MDGVV-16	R	India	Chauhan *et al*. (2018) [10]
	CO 3, CO 4, CO 5	MR	India	Lal (1987) [35]
Stem fly (*Ophiomyia* spp.)	V2396, V3495, V4281	R	Taiwan	Talekar (1990) [77]
	Co 3	R	India	Devasthali and Joshi (1994) [13]
	Chai Nat 72 (CN72)	MR	Thailand	Watanasit *et al*. (2001) [87]
	BM 4 and Vaibhav	R	India	Bhople *et al*. (2017) [9]
Thrips (*Megalurothrips* spp., *Thrips palmi*)	SML 77, UPM 82-4, Pusa 107	R	India	Malik (1990) [38]
	NM-92	R	Pakistan	Khattak *et al*. (2004) [30]
	MGG 362, MGG 365	MR	India	Sandhya Rani *et al*. (2008) [65]
Cowpea aphid (*Aphis craccivora*)	Bari Mung-6	R	Bangladesh	Abdullah-Al-Rahad *et al*. (2018) [1]
	Phule M702-1	R	India	Bhople *et al*. (2017) [9]

*R, Resistant; MR, Moderately resistant.

Furthermore, many techniques can be used for examining the certain genes that are involved in different diseases and other stress condition. For instance, Genome-wide transcriptome profiling gives the data about the genes involved in the response to insect damage. Similarly, molecular markers and QTL mapping techniques have also been used for locating the genes carrying resistance and understanding of the genetic resistance for biotic stresses (Shi *et al*., 2009; Schafleitner *et al*., 2016) [70].

References

1. Abdullah-Al-Rahad M, Rahman MS, Akter T, Akter J, Rahman MA, Aziz SMS. Varietal screening of mungbean against whitefly and aphid. J Biosci. Agric. Res. 2018;18:1478-1487. DOI: 10.18801/jbar.180118.183.
2. Ahmed F, Rafii MY, Ismail MR, Juraimi AS, Rahim HA, Asfaliza R, *et al*. Water logging tolerance of crops: breeding, mechanism of tolerance, molecular approaches, and future prospects. Bio Med research international, 2013. doi:10.1155/2013/963525.
3. Akhtar KP, Sarwar G, Abbas G, Asghar MJ, Sarwar N, Shah TM. Screening of mungbean germplasm against mungbean yellow mosaic India virus and its vector *Bemisia tabaci* Crop Prot. 2011;30:1202-1209. DOI: 10.1016/j.cropro.2011.05.012.
4. Akhtar J, Lal HC, Kumar Y, Singh PK, Ghosh J, Khan Z, *et al*. Multiple disease resistant in greengram and blackgram germplasm and management through chemicals under rain-fed conditions. Leg. Res. 2014;37:101-109. DOI: 10.5958/j.0976-0571.37.1.016.
5. Arun KV, Venkateswarlu B. Abiotic stress in Plants Mechanisms and Adaptations. Intech Web. org, 2011, 1-440.
6. AVRDC. AVRDC Progress Report for (1978). Shanhua, Tainan: Asian Vegetable Research and Development Center, 1979, 173.
7. Bailey-Serres J, Voesenek LA. Flooding stress: acclimations and genetic diversity. Ann. Rev. Plant Biol. 2008;59:313-339. DOI: 10.1146/annurev. arplant. 59.032607.092752.
8. Bhaskar AV. Genotypes against major diseases in green gram and black gram under natural field conditions, A. Vijaya Bhaskar. Int. J Curr. Microbiol. App. Sci. 2017;6:832-843. DOI: 10.20546/ijcmas.2017.606.098.
9. Bhople SK, Dhandge SR, Aravindarajan G, Patange NR. Varietal screening of mungbean genotypes for their resistance against pest complex of mungbean. AGRES 2017;6:123-128.
10. Chauhan R, Singh AK, Sharma KR, Ali A. Screening of mungbean (*Vigna radiata* L.) germplasm against major sucking pest. J Pharm. Phytochem. 2018;7:1784-1787.
11. Chaves MM, Pereira JS, Maroco J, Rodrigues ML, Ricardo CP, Osório ML, *et al*. How plants cope with water stress in the field? Photosynthesis and growth. Annals of botany. 2002;89(7):907-916.
12. Chhabra KS, Kooner BS. Insect pest management in

mungbean and black gram: Status and strategies. IPM System in Agriculture. 1998;4:233-310.
13. Devasthali S, Joshi M. Infestation and varietal preference of insect-pests in green gram. Ind. Agric. 1994;38:263-272.
14. Dutta P, Bera AK. Screening of mungbean genotypes for drought tolerance. Legume Research-An International Journal. 2008;31(2):145-148.
15. Dutta P, Bandopadhyay P, Bera AK. Identification of Leaf based physiological markers for drought susceptibility during early seedling development of mungbean. Am. J Plant Sci. 2016;7:1921-1936. DOI: 10.4236/ ajps.2016.714176.
16. Fernandez GCJ, Shanmugasundaram S. The AVRDC Mungbean Improvement Program: The Past, Present and Future, in Mungbean. Eds. S. Shanmugasundaram and B. T. McLean, Proceedings of the Second International Symposium held at Bangkok, Thailand, 1988, 58-70.
17. Foyer CH, Lam HM, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, *et al*. Neglecting legumes has compromised human health and sustainable food production. Nature plants. 2016;2(8):1-10.
18. Gnanaraj M, Udhayakumar N, Gandhi RR, Manoharan K. Isolation and gene expression analysis of Phospholipase C in response to abiotic stresses from *Vigna radiata* (L.) Wilczek, 2015.
19. Hartman GL, Wang TC, Kim D. Field evaluation of mungbeans for resistance to Cercospora leaf spot and powdery mildew. Int. J Pest. Manag. 1993;39:418-421. DOI: 10.1080/09670879309371833.
20. He X, He T, Xiong Y, Jiao C. Research and use of mungbean germplasm resources in Hubei, China, in Mungbean. Eds. J. Fernandez and S. Shanmugsundaram (Shanhua, Tainan: Asian Vegetable Research and Development Centre), 1988, 35-41.
21. Itoh T, Garcia RN, Adachi M, Maruyama Y, Tecson-Mendoza EM, Mikami B, *et al*. Structure of 8Sα globulin, the major seed storage protein of mung bean. *Acta crystallographica* section D: *Biological crystallography*. 2006;62(7):824-832. DOI: 10.1107/S090744490601804X.
22. Iqbal SM, Zubair M, Haqqani AM. Resistant in Mungbean to *Cercospora* leaf spot disease. Int. J Agric. Biol. 2004;06:792-793.
23. Kang YJ, Kim SK, Kim MY, Lestari P, Kim KH, Ha BK, *et al*. Genome sequence of mungbean and insights into evolution within Vigna species. Nature communications. 2014;5(1):1-9.
24. Karademir C, Karademir E, Copur O, Gencer O. November). Effect of drought stress on leaf area in cotton (*Gossypium hirsutum* L.). In 11th Meeting of Inter-Regional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions, 2012, 5-7 pp.
25. Kaewwongwal A, Chen J, Somta P, Kongjaimun A, Yimram T, Chen X, *et al*. Novel alleles of two tightly linked genes encoding polygalacturonase-inhibiting proteins (VrPGIP1 and VrPGIP2) associated with the Br locus that confer bruchid (*Callosobruchus* spp.) resistance to mungbean (*Vigna radiata*) accession V2709. Frontiers in plant science. 2017;8:1692. DOI: 10.3389/fpls.2017.01692.
26. Kaloyereas SA. A New Method of Determining Drought Resistance. Plant Physiology. 1958;33(3):232.
27. Kaur L, Singh P, Sirari A. Biplot analysis for locating multiple disease resistant diversity in mungbean germplasm. Dis. Res. 2011;26;55-60.
28. Kaur R, Kaur J, Bains TS. Screening of mungbean genotypes for drought tolerance using different water potential levels. J Adv. Agric. Tech. 2017;4:2-18. DOI: 10.18178/joaat.4.2.159-164.
29. Khattak GSS, Haq MA, Ashraf M, Elahi T. Genetics of Mungbean Yellow Mosaic Virus (MYMV) in mungbean (*Vigna radiata* L.) Wilczek. Journal of Genetics & Breeding. 2000;54(4):237-243.
30. Khattak MK, Shafqat A, Chisti JI. Varietal resistance of mungbean (*Vigna radiata* L.) against whitefly (*Bemisia tabaci* Genn.), jassid (*Amrasca devastans* Dist.), and thrips (*Thrips tabaci* Lind.). Pak. Entomol. 2004;26:9-12.
31. Kooner BS, Chhabra KS, Arora BS. Resistant sources in mungbean to manage whitefly, jassids and yellow mosaic virus. In: Proceedings of third agricultural science congress. PAU Ludhiana, India. 1997 Mar; 2:12-15.
32. Kooner BS, Cheema HK. Screening of mungbean germplasm against whitefly, *Bemisia tabaci* and MYMV. Acta Hortic. 2007;752:307-310. DOI: 10.17660/ActaHortic.2007.752.52.
33. Kumar S, Kumar R. Genetic improvement of mungbean for yield, nutrition and resistance to stresses-A review. Int. J Trop. Agril. 2014;32(3-4):683-687.
34. Kumar S, Tanti B, Patil BL, Mukherjee SK, Sahoo L. RNAi-derived transgenic resistance to Mungbean yellow mosaic India virus in cowpea. PLoS One. 2017;12:e0186786. DOI: 10.1371/journal.pone.0186786.
35. Lal SS. Insect-pests of mungbean, urd, cowpea, and pea and their management, in Plant protection in field crops. Eds. VM Rao and S Sithanantham (Hyderabad: Plant Protection Association of India), 1987, 185-202.
36. Liu JJ, Ekramoddoullah AK. The family 10 of plant pathogenesis-related proteins: their structure, regulation, and function in response to biotic and abiotic stresses. Physiological and molecular plant pathology. 2006;68(1-3):3-13.
37. Lee YB. 1. Inheritance study on resistance to powdery mildew and sensitivity to photoperiod in mungbean. 2. Inheritance study on resistance to Cercospora leaf spot in mungbean. 3. Inheritance study on number of leaflets in mung beans (No. research). AVRDC, 1980.
38. Malik SPS. Comparative resistance of summer mungbean genotype to the thrips, *Megalurothrips distalis* (Karny.), M.Sc. thesis, Punjab Agricultural University, Ludhiana, 1990.
39. Maliwal GL, Paliwal KV. Salt tolerance of some mungbean (*Vigna radiata*), urdbean (*Vigna mungo*) and guar (*Cyamopsis tetragonoloba*) varieties at germination and early stages. Leg. Res. 1982;5:23-30.
40. Manasa R, Rameshreddy K, Bindumadhava H, Nair RM, Prasad TG, Shankar AG. Screening mungbean (*Vigna radiata* L.) lines for salinity tolerance using salinity induction response technique at seedling and physiological growth assay at whole plant level. Intl J Plant Anim. Environ. Sci. 2017;7:1-12. DOI: 10.21276/Ijpae
41. Mandhare VK, Suryawanshi AV. Dual resistant against powdery mildew and yellow mosaic virus in green gram. Agric. Sci. Digest. 2008;28:39-41.

42. Mansoor-Ul-Hassan AR, Akbar R, Latif A. Varietal response of mung and mash beans to insect attack. Pak J Entomol. 1998;20:43-46.
43. Marappa N. Screening of mungbean genotypes and its wild relatives for resistant sources to Cercospora leaf spot disease. Asian J Bio. Sci. 2008;3:324-326.
44. Markam NK, Nair SK, Nanda HC, Lakpale N. Studies on allelic relationship for resistance to mungbean yellow mosaic virus disease in mungbean genotypes. Int. J Chem. Stud. 2018;6(2):2401-2403.
45. Marimuthu G, Rajan S, Chandrashekaran MK. Social entrainment of the circadian rhythm in the flight activity of the microchiropteran bat Hipposideros speoris. Behavioral Ecology and Sociobiology, 1981, 147-150. DOI: 10.1007/ BF00300827.
46. Mehdy MC. Active oxygen species in plant defense against pathogens. Plant physiology. 1994;105(2):467.
47. Misra N, Gupta AK. Interactive effects of sodium and calcium on proline metabolism in salt tolerant green gram cultivar. Am. J Plant Physiol. 2006;1:1-12. DOI: 10.3923/ajpp.2006.1.12
48. Muhammad AK, Sajjad H, Yasir A. Evaluation of mung bean germplasm for resistance against mung bean yellow mosaic virus and whitefly population in relation to epidemiological factors. Agric. Res. Tech: Open Access J. 2018;18:556058. DOI:10.19080/ARTOAJ.2018.18.556058
49. Nadeem S, Hamed M, Asghar MJ, Abbas G, Saeed NA. Screening of mungbean (*Vigna radiata* (L.) Wilczek) genotypes against sucking insect-pests under natural field conditions. Pak. J. Zool. 2014;46:863-866.
50. Naher N, Alam AK. Germination, growth and nodulation of mungbean (*Vigna radiata* L.) as affected by sodium chloride. Int. J Sustain. Crop Prod. 2010;5(2):8-11.
51. Pan J, Sharif R, Xu X, Chen X. Mechanisms of water logging tolerance in plants: Research progress and prospects. Frontiers in Plant Science, 2021, 2319.
52. Pandey AK, Burlakoti RR, Kenyon L, Nair RM. Perspectives and challenges for sustainable management of fungal diseases of mungbean [*Vigna radiata* (L.) R. Wilczek var. radiata]: A Review. Frontiers in Environmental Science. 2018;6:53. DOI: 10.3389/fenvs.2018.00053.
53. Pandiyan M, Subbalakshmi B, Alice D, Marimuthu R. Screening of Mungbean [*Vigna radiata* (L.) Wilczek] germplasm for mungbean yellow mosaic virus. Plant Arch. 2007;7:375-376.
54. Panduranga GS, Vijayalakshmi K, Loka RK, Rajashekara H. Evaluation of mungbean germplasm for resistance against whitefly (*Bemisia Tabaci* Genn.) and mungbean yellow mosaic virus (MYMV) disease. Ind. J Entomol. 2011;73:338-342.
55. Parida A, Raina SN, Narayan RKJ. Quantitative DNA variation between and within chromosome complements of *Vigna* species (Fabaceae). Genetica. 1990;82:125-133. DOI: 10.1007/BF00124642.
56. Patel PN, Jindal JK. Bacterial leaf spot and halo blight diseases of mung bean (Phaseolus aureus) and other legumes in India. Indian phytopathology, 1972.
57. Patel MB, Srivastava KP. Field screening of some high yielding genotypes of mungbean, *Vigna radiata* (Linnaeus) Wilczek to whitefly *Bemisia Tabaci* (Gennadius) and yellow mosaic virus (YMV). Ind. J Entomol. 1990;52:547-551.
58. Paul PC, Biswas MK, Mandal D, Pal P. Studies on host resistance of mungbean against mungbean yellow mosaic virus in the agro-ecological condition of lateritic zone of West Bengal. Bioscan. 2013;8:583-587.
59. Pratap A, Gupta S, Basu PS, Tomar R, Dubey S, Rathore M, *et al*. Towards development of climate smart mungbean: challenges and opportunities. In Genomic Designing of Climate-Smart Pulse Crops, 2019, 235-264 pp. Springer, Cham. DOI: 10.1007/978-3-319-96932-9_5.
60. Premachandra GS, Saneoka H, Fujita K, Ogata S. Leaf water relations, osmotic adjustment, cell membrane stability, epicuticular wax load and growth as affected by increasing water deficits in sorghum. Journal of experimental botany. 1992;43(12):1569-1576.
61. Promila K, Kumar S. Vigna radiata seed germination under salinity. *Biologia Plantarum*. 2000;43(3):423-426. doi: 10.1023/A:1026719100256.
62. Raina SK, Govindasamy V, Kumar M, Singh AK, Rane J, Minhas PS. Genetic variation in physiological responses of mungbeans (*Vigna radiata* (L.) Wilczek) to drought. Acta Physiol. Plant. 2016;38:263. DOI: 10.1007/ s11738-016-2280-x.
63. Reddy KS. A new mutant for yellow mosaic virus resistance in Mungbean (*Vigna radiata* (L.) Wilczek) variety SML-668 by Recurrent Gamma-ray Irradiation. Induced plant mutation in the genomics era, 2009, 361-362.
64. Salam SA, Patil MS, Salimath PM. Evaluation of mungbean cultures against MYMV in Karnataka under natural conditions. Leg. Res. 2009;32:286-289.
65. Sandhya Rani C, Eshwari KB, Sudarshanam A. Field screening of greengram (*Vigna radiata* L.) entries against thrips (*Thrips palmi*) and spotted pod borer (*Maruca vitrata*). J Res. ANGRAU. 2008;36:17-22.
66. Sekar S, Nalini R. Varietal Screening of Mungbean Genotypes against Whitefly (Bemisia tabaci Genn.), Mungbean Yellow Mosaic Virus (MYMV) and Cercospora leaf Spot. Int. J Curr. Microbial. App. Sci. 2017, 61278-1285. DOI: 10.20546/ijcmas.2017.603.147.
67. Sehrawat N, Bhat KV, Kaga A, Tomooka N, Yadav M, Jaiwal PK. Development of new gene-specific markers associated with salt tolerance for mungbean (*Vigna radiata* L. Wilczek). Spanish J Agric Res 2014;12(3):732-741. DOI: 10.5424/sjar/2014123-4843
68. Shakeel S, Mansoor S. Salicylic acid prevents the damaging action of salt in mungbean [(*Vigna radiata* L.) Wilczek] seedlings. Pak. J Bot. 2012;44:559-562.
69. Shad N, Mughal SM, Farooq K, Bashir M. Evaluation of mungbean germplasm for resistance against mungbean yellow mosaic begomovirus. Pak. J Bot. 2006;38:449-457.
70. Shi A, Chen P, Li D, Zheng C, Hou A, Zhang B. Gene pyramiding of genes of soybean mosaic virus resistance. Mol. Breed. 2009;23:113-124. DOI: 10.1007/s11032-008-9219-x.
71. Singh G, Sharma YR, Shanmugasundaram S, Shih SL, Green SK. Improving income and nutrition by incorporating mungbean in cereal fallows in the Indo-Gangetic Plains of South Asia DFID Mungbean Project for 2002-2004. in Proceedings of the Final Workshop and Planning Meeting, Status of Mung Bean Yellow Mosaic

Virus Resistance Breeding. Ludhiana: Punjab Agricultural University, 2004 May, 27-31, 204-213.
72. Singh DP, Singh BB. Breeding for tolerance to abiotic stresses in mungbean. Journal of food legumes. 2011;24(2):83-90.
73. Singh SP, Singh SK. Sources of resistant in mungbean for *Cercospora* leaf spot diseases. Ann. Agric. Biosci. Res. 2014;2:280-281.
74. Snapp SS, Blackie MJ, Gilbert RA, Bezner-Kerr R, Kanyama-Phiri GY. Biodiversity can support a greener revolution in Africa. Proceedings of the National Academy of Sciences. 2010;107(48):20840-20845.
75. Sundaresan S, Sudhakaran PR. Water stress-induced alterations in the proline metabolism of drought-susceptible and-tolerant cassava (Manihot esculenta) cultivars. *Physiologia Plantarum*. 1995;94(4):635-642.
76. Swaminathan R, Singh K, Nepalia V. Insect-pests of green gram *Vigna radiata* (L.) Wilczek and their management. Agricultural science, 2012;10:197-222. doi: 10.5772/35176.
77. Talekar NS. Agromyzid flies of food legumes in the tropics. Agromyzid flies of food legumes in the tropics, 1990.
78. Thakur RP, Patel PN, Verma JP. Genetical relationships between reactions to bacterial leaf spot, yellow mosaic and Cercospora leaf spot diseases in mungbean (*Vigna radiata*). Euphytica. 1977;26(3):765-774. DOI: 10.1007/BF00021705.
79. Toker C, Mutlu N, Pratap A, Kumar J. Biology and Breeding of Food legumes. Chapter. 2011;16:241-260. doi: 10.1079/9781845937669.0241.
80. Tripathy S, Mohanty P, Jena M, Dash S, Lenka D, Mishra D, *et al*. Identification of seed storage protein markers for drought tolerance in mungbean. Res. Biotechnol. 2016;7:3-11. DOI: 10.19071/rib.2016.v7.2895
81. Yadav DL, Jaisani P, Pandey RN. Identification of sources of resistant in mungbean genotypes and influence of fungicidal application to powdery mildew epidemics. Int. J Curr. Microbiol. Appl. Sci. 2014a;3:513-519.
82. Yadav DL, Pandey RN, Jaisani P, Gohel NM. Sources of resistant in mungbean genotypes to Cercospora leaf spot disease and its management. Afr. J Agric. Res. 2014b;9:3111-3114. DOI: 10.5897/AJAR2014.8860.
83. Yadav GS, Dahiya B. Performance of mungbean genotypes against whitefly and yellow mosaic. Ann. Biol. 2004;20:57-59.
84. Walter MH, Liu JW, Grand C, Lamb CJ, Hess D. Bean pathogenesis-related (PR) proteins deduced from elicitor-induced transcripts are members of a ubiquitous new class of conserved PR proteins including pollen allergens. Molecular and General Genetics MGG. 1990;222(2):353-360.
85. Wang LF, Jing WU, Jing RL, Cheng XZ, Wang SM. Drought resistance identification of mungbean germplasm resources at seedlings stage. Acta Agron. Sin. 2015;41:145-153. DOI: 10.3724/SP.J.1006.2015.00145
86. Wang LF, Jing WU, Jing RL, Cheng XZ, Wang SM. Drought resistance identification of mungbean germplasm resources at bud stage. J Plant Genet. Resour. 2014-15, 498-503.
87. Watanasit A, Ngampongsai S, Thanomsub W. The use of induced mutations for mungbean improvement. Report of an FAO/IAEA Seminar on Mutation Techniques and Molecular Genetics for Tropical and Subtropical Plant Improvement in Asia and the Pacific Region. 1999, in The Philippines.1999-2001 Oct11-15, 11-12.
88. Wongpiyasatid A, Chotechuen S, Hormchan P, Srihuttagum M. Evaluation of yield and resistance to powdery mildew, Cercospora leaf spot and cowpea weevil in mungbean mutant lines. Kasetsart J (Nat. Sci.) 1999;33:204-215.
89. Zhang K, Jin C, Wu L, Hou M, Dou S, Pan Y. Expression analysis of a stress-related phosphoinositide-specific phospholipase C gene in wheat (*Triticum aestivum* L.). PloS one. 2014;9(8):e105061.