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MULTIPLE-DISEASE RESISTANCE IN GRAIN LEGUMES

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INTRODUCTION

The term multiple-disease resistance (MDR) can be defined as host-plant resistance to two or more diseases. In most programs to breed plants resistant to disease, successes in developing crop cultivars resistant to single diseases are achieved in a relatively short time. However, real farm situations require cultivars having combined resistance not only to more than one disease, but also to other important biotic and abiotic stress factors. While some stress factors, such as insect pests and micronutrient deficiencies, can be managed by means other than host resistance, the successful management of crop diseases most often requires the availability of resistant cultivars.

The concept of MDR in crops is not new. As far back as 1902, the cowpea cultivar Iron was found to be resistant to wilt and root-knot (52, 64). Since then MDR has been a major objective of research of many pathologists and breeders working on different crops. For example, the wheat cultivars Hope and H-44 have combined resistance to leaf and stem rusts, as well as to loose and covered smuts (7). Successful MDR has been achieved in crops such as beans, cabbage, corn, cotton, cucumber, sugarbeet, tobacco, and tomato (8, 17, 63, 65).

The importance of grain legumes in the world farming systems, as well as in human nutrition, has been emphasized in recent years (32). Production of many grain legumes is insufficient relative to the needs of human nutrition, particularly in the developing countries, where the "green revolution" has occurred only in cereal production. While the world productivity of several legumes averages around 600–700 kg/ha^{-1}, it has been demonstrated that the yield potential is over 3000 kg/ha^{-1} (49). Amongst the factors responsible for

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reducing yields, diseases figure very prominently. There is a need for MDR in several grain legumes because (*a*) the number of diseases responsible for yield reduction is large, and (*b*) because several of these legumes are grown by resource-poor farmers of developing countries.

This article reviews the present status of, and problems in breeding cultivars with MDR, and examples of MDR in important grain legumes grown around the world. Soybean and peanut have not been included because normally these crops are considered as oilseeds rather than grain legumes.

PRESENT STATUS

Interest in multiple-disease resistance in legumes, particularly those widely cultivated in developing countries, has been slight, or has increased only in recent years. Such crops are: chickpea (*Cicer arietinum* L.); pigeonpea (*Cajanus cajan* (L.) Millsp.); cowpea (*Vigna unguiculata* (L.) Walp.); fava bean (*Vicia faba* L.); lentil (*Lens culinaris* Medik); and mungbean (*Vigna radiata* (L.) Wilczek). Multiple-disease resistance even in pea (*Pisum sativum* L.) has not received much attention. Grain legumes suffer from a large number of diseases caused by fungi, bacteria, viruses, nematodes, etc. The author does not know of any location, either from the literature surveyed or from his travels in many countries, where a legume crop does not suffer losses from at least two diseases. Different grain legumes suffer from a wide range of diseases such as wilts, root rots, downy and powdery mildews, leaf spots and blights, rusts, mosaics, and/or stunted growth resulting from attack by root-knot or cyst nematodes.

During the last two decades, four international agricultural research centers (IARCs), established under the auspices of the Consultative Group for International Agricultural Research (CGIAR), have been carrying out extensive work on the genetic improvement of several grain legumes grown commonly in many developing countries. These IARCs are: Centro Internacional de Agriculture Tropical (CIAT) in Colombia; International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India; and International Institute of Tropical Agriculture (IITA) in Nigeria. In addition, the Asian Vegetable Research and Development Center (AVRDC) in Taiwan is doing useful work on mungbean. These centers have concentrated their research work on generating breeding materials that are capable of giving high and stable yields over a wide range of agroclimatic conditions. In their efforts to improve stability of performance of breeding lines, researchers at these centers have focused their attention on disease resistance, particularly MDR. For improved cultivars with MDR, or even better, with multiple-stress tolerance, must be available to the resource-poor farmers in developing countries if they are to obtain yields higher than those obtainable from the local land races. Some information on MDR in grain legumes is thus available at present, and we should expect a considerable increase in our knowledge of MDR by the end of the twentieth century.

PROBLEMS

Availability of Germ Plasm

To have a meaningful MDR breeding program in any crop, it is necessary that pathologists and breeders have easy access to a wide range of germ plasm. Owing to the general awareness of the ongoing loss of genetic material that has accompanied rapid introduction of improved cultivars of crops, attempts are currently being made worldwide to preserve the available and valuable land races of many crop plants. During the last two decades, the establishment of IARCs, including the International Board for Plant Genetic Resources (IBPGR) with headquarters at the Food and Agriculture Organization of the United Nations (FAO) in Rome, has greatly helped in the collection and maintenance of germ plasm of various crops throughout the world. It is gratifying to see that IARCs are freely sharing the germ plasm and breeding material with national programs.

It would be appropriate to have a look at the germ-plasm collections for some of the grain legumes that are available for a disease-screening program (Table 1).

Table 1 Germ-plasm accessions of grain legumes maintained at different locations

Location	Crop	Germplasm accessions[a]	Reference(s)
ICRISAT	Chickpea	15,200	Personal communication, M. H. Mengesha
	Pigeonpea	11,000	
	Groundnut	11,600	
ICARDA	Faba bean	3,300	29, 31
	Lentil	6,200	
CIAT	Dry beans	35,000	11
IITA	Cowpea	11,800	39
AVRDC	Mungbean	4,900	5
	Soybean	9,300	
Univ. of Illinois, USA	Soybean	7,300	23
NGB, Lund, Sweden	Dry peas	20,500	12

[a]Number rounded off to the nearest hundred.

Obtaining Multiple Disease Resistances

If we critically analyze the existing situation with regard to any grain legume, particularly one that has not received much attention from the breeders, we quickly realize that most low-yielding land races of certain crops already possess a level of multiple-disease resistance that is acceptable to farmers of that region; otherwise farmers would not continue to cultivate such a legume. For example, as many as 20 foliar fungal pathogens have been reported on pigeonpeas in India (51). The crop land races "live" with most of these pathogens at a given location apparently without losing much yield. An exception is *Alternaria tenuissima* (Kunze ex. Pers.) Wittshire, which causes a severe blight of a crop sown in the post-rain season rather than in the normal rainy season. Another good example exists in chickpeas. The author has observed that the cultivar PRR-1, obtained from Mexico, is severely affected in India by the powdery mildew (*Leveillula taurica* (Lev.) Arnaud) and rust (*Uromyces ciceris-arietini* (Grogn.) Jacz. & Beyer), in contrast to the very large number of cultivars and germ-plasm accessions of Indian origin that show no mildew and only traces of rust, if any at all. This clearly indicates that the inocula exist, but that the local land races have acceptable levels of resistance to these two diseases. Thus when land races are subjected to genetic-improvement efforts in the region of their adaptation, and germ plasm from other regions is used in making the crosses, some of the new breeding lines that are generated may lack locally useful resistances.

Obtaining MDR is not always easy. To locate germ-plasm accessions having resistance to two diseases has not normally been difficult, but the task becomes more challenging when one is looking for resistance to three or more diseases. When a breeder wants to add to germ plasm resistance to more than two diseases, his task becomes quite difficult. Sometimes lines resistant to one stress factor may be highly to susceptible to another. In the case of both chickpeas and pigeonpeas, when ICRISAT entomologists identified lines resistant to *Heliothis armigera* (Hb.), they found these to be highly susceptible to Fusarium wilts (*Fusarium oxysporum* f.sp. *ciceri* and *F. udum*).

Screening Methods

One of the major tasks for pathologists is to develop simple, practical, and efficient procedures for screening germ plasm and breeding materials for resistance against diseases. Depending upon the local situations, the screening procedures have to be developed so that they identify resistance against either a single disease or several diseases. Screening for MDR can be done either with sequential screening or with simultaneous screening for resistance to the diseases. Both sequential and simultaneous MDR screenings have their own merits, and both types of procedures have been successfully used in legumes (24, 34).

In the literature, one finds many papers describing laboratory- and glasshouse-screening procedures. Often these are very useful, but ultimate success in obtaining resistance, single or multiple, depends upon how relevant these techniques are to what happens when the crops are actually grown under field conditions. The author feels that screening for resistance should normally be carried out in the field, and that laboratory and glasshouse procedures should be developed only as a supplement to field screening.

Pathogen Variability

MDR involves more than one pathogen, and each pathogen may have several races. This not only complicates the situation, but poses a real challenge to pathologists and breeders working on MDR. The choice of whether to use one or more races of each pathogen in screening is a very difficult one, and sometimes causes breeders and pathologists frustration. Occasionally, in a MDR nursery, the race situation changes, upsetting the planned program. For example, while the race situation in Fusarium wilt and sterility mosaic has remained the same over the last 10 years in the pigeonpea-MDR nursery at ICRISAT Center, race shifts have occurred twice in the case of Phytophthora blight.

Some pathogens are inherently unstable. *Ascochyta rabiei* (Pass.) Labr., an important pathogen on chickpea, is a good example. In the author's laboratory, some *Ascochyta* single-spore cultures produced morphological variants. While it is yet to be established whether these morphological variants are also pathological variants, such a possibility cannot be ruled out. Reports of the occurrence of the perithecial stage (*Mycosphaerella rabiei* Kovacevsky) in several countries further complicates the situation and can explain why chickpea lines identified as resistant do not remain so for very long. At the ICARDA Center farm at Tal Hadia in Syria, as many as 6 races of *A. rabiei* have been identified (M. V. Reddy, personal communication). The possibility of *Ascochyta* inoculum being brought from other regions through rain storms has not yet been ruled out; if that happens, *Ascochyta* resistance in chickpeas may never really hold in nature, and it would be necessary to look for a package of practices, including resistance, to manage the disease. As pointed out earlier, most legumes suffer from soilborne pathogens such as wilt and root rot fungi. By and large, pathogen variability has not created serious problems in handling soilborne diseases in chickpea, pigeonpea, dry beans, dry peas, and lentils, for the resistance used has been stable and durable, and the pathogen-race situation is better manageable than in the case of several foliar pathogens.

EXAMPLES OF MULTIPLE-DISEASE RESISTANCE

The author has direct experience of working on the MDR in pigeonpeas and chickpeas, and therefore more details related to MDR in these two crops have been given. Information on MDR generated in pigeonpeas and chickpeas is relevant to other crops, and therefore the details given herein should be useful.

Pigeonpeas

Pigeonpeas suffers from three major diseases in the Indian subcontinent, where over 90% of the world crop is grown (15). These are: sterility mosaic (virus ?); Fusarium wilt (*Fusarium udum* Butler); and Phytophthora blight (*Phytophthora dreschleri* Tucker f.sp. *cajani* (Pal et al; Kannaiyan et al). Surveys undertaken revealed that in India alone, the estimated annual loss caused by sterility mosaic and Fusarium wilt has the monetary value of US $76 million and $37 million, respectively (41). Losses due to Phytophthora blight have not been estimated, but a pigeonpea in badly drained areas can be totally devastated, particularly when the rainfall is greater than normal.

At ICRISAT Center, Nene et al (50) developed and standardized techniques to screen for resistance to these three diseases under field conditions. The "sick plot" technique was adapted for Fusarium wilt. The technique consisted of uniformly growing highly wilt-susceptible cultivars for two seasons and chopping and uniformly incorporating all the dead plant debris into the soil. Such a plot is then ready for screening. During the screening, every third row is planted with a susceptible cultivar. These rows serve as checks and help in monitoring as well as maintaining the wilt "sickness" of the plot. Susceptible checks show 90–100% wilt. The Phytophthora blight pathogen survives in infected stubble left in the field (37). The screening technique for this disease involves (*a*) multiplication of inoculum in the laboratory; (*b*) stem-base inoculation of one-month-old plants (to be repeated after one month); and (*c*) flood-irrigation of the plot (to be repeated after one week). Rows of susceptible cultivar are planted throughout the plot at frequent intervals to monitor the disease pressure. The causal agent of sterility mosaic is vectored by an eriophyid mite (*Aceria cajani* Channabasavanna). The disease spreads through infective mites disseminated by wind and the field-screening technique is based on this dissemination. Four rows of a susceptible cultivar are planted 4–6 months in advance upwind of the plot that has been earmarked for screening in the next season. The plants in the infector rows, when 3–4 weeks old, are inoculated by the leaf-stapling technique (50). These plants become infected, allow multiplication of the vector, and form a hedge. Consequently, this method of screening is referred to as the "infector-hedge technique." The test material is planted at the normal sowing time along with interspersed rows of a susceptible check cultivar. When the wind blows over the infector hedge, the infective mites move on to the test rows and the disease spreads. While the mites can be disseminated downwind from the hedge up to a distance of 2 km (36), the distance for effective screening

(100% infection of a susceptible cultivar) has been found to be around 200 meters.

To screen breeding material simultaneously for resistance to these three diseases, the author and his colleagues have been using a system that combines the three procedures described above into one. A Fusarium wilt-sick plot of 1.2 ha has been developed. An infector hedge is planted in advance upwind of the plot. After test rows are planted in the field, inoculations with *Phytophthora* are carried out. The mosaic starts appearing on susceptible plants in about three weeks. *Phytophthora* inoculations knock out susceptible plants or cause them to show lesions within 70 days after sowing, and the Fusarium wilt appears around flowering time. Thus the pigeonpea material is screened simultaneously for the three diseases. Appropriate susceptible check cultivars, which are susceptible to one disease but not to the other two, are planted at regular intervals to monitor the maximum severity of each disease in the nursery.

Phytophthora blight is not as widespread a problem as Fusarium wilt and sterility mosaic. Therefore, at ICRISAT Center the author and his colleagues operate a 1.5 ha two-disease nursery, where a wilt-sick plot is provided with the sterility-mosaic infector hedge, but no inoculations with *P. drechsleri* f.sp. *cajani* are carried out. This allows generation of breeding materials for those areas where soils are well-drained and Phytophthora blight is therefore not a problem.

Lines identified as resistant are tested at several locations all over India through the All India Coordinated Pulses Improvement Project. Such a testing has helped in identification of several stable sources of resistance to the Fusarium wilt and sterility mosaic. The author has tested some of the resistant lines for over a decade now and finds that the resistances to wilt and mosaic are durable. However, *P. drechsleri* f.sp. *cajani* has shown considerable variability and it has been difficult to identify stable and durable resistance.

As a result of these efforts in pigeonpeas, a few lines with MDR have been identified, and these are listed in Table 2.

Table 2 Some examples of multiple disease resistance in pigeonpeas[a]

Cultivars/lines	Resistant to
ICP 7198, 8024, 8860 to 8862, 9142, 10960, PR 5149, ICPL 83-227	Wilt, sterility mosaic
ICP 11302 to 11304	Wilt, sterility mosaic, Phytophthora blight
ICP 8861, 8862, 10960	Wilt, sterility mosaic, Alternaria blight
64-16A[b]	Rust, leaf spots (*Colletotrichum* sp. *Cercospora* sp., *Phoma* sp.)

[a]Information based on work done by the author and his colleagues at ICRISAT Center, except that obtained from Ref. 56.
[b]Ref. 56.

Fusarium wilt and Cercospora leaf spot (*Cercospora cajani* Hennings) are commonly observed in Kenya, Uganda, and Tanzania (51). While some of the lines identified by ICRISAT have been found resistant to wilt in Kenya and Malawi (36), and some lines have been identified as resistant to Cercospora leaf spot in Kenya (35), there has been no effort in that region to obtain combined resistance to these two diseases.

Chickpea

Ascochyta blight, Botrytis gray mold (*Botrytis cinerea* Pers. ex. Fr.), Fusarium wilt, and dry root rot (*Rhizoctonia bataticola* (Taub.) Butler) are major diseases of chickpea (51). While losses due to Botrytis gray mold have not been estimated, the author has observed its potential to devastate the crop in the submontane region of northern India, as well as in Bangladesh and Nepal. Losses in Pakistan and Syria (55) and parts of India in recent years due to Ascochyta blight have been substantial. The damage in Pakistan resulted in a severe shortage of grain legumes, and the value of imported grain legumes in 1983 reached US $7.43 million (Bashir Malik, personal communication). Wilt and root rots together cause an annual loss of 10% of the crop in India (33).

ICRISAT scientists have been able to identify combined resistance/tolerance to Fusarium wilt and root rots caused by *Rhizoctonia bataticola, Fusarium solani* (Mart.) Sacc., and *R. solani* Kuhn (37). The screening procedure followed was similar to that described earlier for pigeonpea Fusarium wilt, except that the diseased crop debris included chickpeas that had been killed by root rots as well as by the Fusarium wilt. At ICRISAT Center, the author and his colleagues have maintained multiple soilborne disease nurseries covering over 5 ha, where a very large amount of breeding material is screened every year against the soilborne diseases listed above..

Multilocational testing for Fusarium wilt and root rots has been carried out through cooperation between national programs and ICRISAT and stable resistance has been found (38). As many as 6 races of *Fusarium oxysporum* f.sp. *ciceri* have been identified so far, 4 in India (26) and 2 in Spain (9). It is possible that other distinct races exist in Tunisia and the United States. In spite of such a race picture, it has not been difficult to identify a high level of stable resistance that is functional at most locations. Also resistance may turn out to be durable, since the author has found that the lines CPS-1 and ICC 8933 have retained their resistance in India for over 10 years.

While resistance to Fusarium wilt and root rots (particularly the dry root rot caused by *R. bataticola*) has been stable and durable, the resistance to Ascochyta blight has broken down. Even during the period of development of chickpea ILC 482, a line that is highly resistant to race 3 at ICARDA (M. V. Reddy, personal communication), it showed susceptibility to new races (races

4, 5, and 6). In Pakistan, CM-72 that was identified and released as resistant to Ascochyta blight in 1985, showed susceptibility in 1987 in several areas (Mohamad Bashir, personal communication). The gray mold fungus also has races (J. S. Grewal, personal communication). The production of a high yielding cultivar with stable resistance to Fusarium wilt, root rots, Ascochyta blight, and Botrytis gray mold will, at best, be a very long-term project. A few examples of combined resistance are given in Table 3.

Cowpea

Anthracnose (*Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri and Cav.), Cercospora leaf spot (*Pseudocercospora cruenta* (Sacc.) Deighton), Ascochyta blight (*Ascochyta phaseolorum* Sacc.), and mosaics (Cowpea aphidborne mosaic virus-CAbMV; cowpea mosaic virus-CPMV) are major diseases of cowpea. Losses of up to 50% caused by anthracnose have been recorded in Nigeria, and defoliation due to Cercospora leaf spot can lead to over 40% loss of projected yield (3). Ascochyta blight causes severe losses under cooler conditions at elevations above 1000 m in Africa and in Central America. The two mosaic viruses are more widespread than other viruses affecting cowpeas and cause heavy losses in Africa; at IITA, therefore, all promising germ plasm and advanced breeding lines are routinely screened for resistance against these two viruses (61).

As mentioned in the introduction, MDR (against wilt and root-knot) was first reported in cowpea in 1902 (52, 64). Subsequently, several other researchers have reported lines that combined resistance to these two diseases (3). In 1974, IITA initiated an international testing program for germ plasm that was found to possess combined resistance to two or more diseases in Nigeria. This program led to the identification of several cowpea lines possessing MDR (61).

The screening techniques followed at IITA involve a combination of procedures using natural and supplemented infestation in the field, and inoculation techniques in the glasshouse. Scattering infected plant debris within the test plant canopy has been found adequate for screening for resistance against bacterial blight (*Xanthomonas campestris* pv. *vignicola* Burk.), Sep-

Table 3 Some examples of multiple-disease resistance in chickpeas[a]

Cultivars/lines	Resistant to
ICC 12237-12269	Fusarium wilt, dry root rot, black root rot
ICC 1069	Fusarium wilt, Ascochyta blight, Botrytis gray mold
ICC 10466	Fusarium wilt, dry root rot, stunt
ICC 858, 959, 4918, 8933, 9001	Fusarium wilt, Sclerotinia stem rot

[a]Information based on work done by the author and his colleagues at ICRISAT Center.

toria leaf spot (*Septoria* spp.), Cercospora leaf spot (*Cercospora* spp.), rust (*Uromyces appendiculatus* (Pers.) Ung.), and scab (*Sphaceloma* sp.). See Table 4 for some examples of MDR in cowpeas.

Dry Beans

Anthracnose (*Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav.), rust (*Uromyces phaseoli* (Reben) Wint.), angular leaf spot (*Isariopsis griseola* Sacc.), Fusarium root rot (*Fusarium solani* (Mart.) Appel and Wollenw. f.sp. *phaseoli* (Burk.) Snyder & Hansen), and the common mosaic (bean common mosaic virus-BCMV) are the most important diseases of dry beans (*Phaseolus vulgaris* L.) around the world. Anthracnose, rust, and the common mosaic can cause losses of over 95%, and angular leaf spot and Fusarium root rot up to 80% of the expected yield (58).

The literature on disease resistance in dry beans is perhaps more extensive than that on any other grain legume (3, 27, 58). However, MDR remains relatively uncommon among commercial cultivars.

To screen for MDR, workers have used infected crop debris, planted spreader rows of susceptible cultivars, and depended on high natural incidence (46). For soilborne diseases, a permanent disease nursery (sick plot) is used (1).

Major pathogens (e.g. *C. lindemuthianum, U. phaseoli*) of beans show considerable variability through distinct races, and this makes the task of breeding MDR extremely difficult. It is understandable, therefore, that fungicides are widely used for controlling some of the fungal diseases. Table 5 gives a few examples of MDR in dry beans.

Pea

Downy mildew (*Peronospora viciae* (Berk.) de Bary), powdery mildew (*Erysiphe polygoni* DC), rust (*Uromyces viciae-fabae* (Pers.) Schroet. and *U. pisi* (Pers.) Wint.), and wilt (*Fusarium oxysporum* Schl. f.sp. *pisi* (van Hall)

Table 4 Some examples of multiple-disease resistance in cowpeas

Cultivars lines	Resistant to	Reference(s)
VITA 1	brown blotch, root-knot	60
VITA 4	bacterial blight, scab, *Septoria* sp., *Colletotri chum* sp.	4
Iron	Fusarium wilt, root-knot, anthracnose, rust, Cercospora leaf spot, bacterial pustule, bacterial blight, cowpea banding mosaic, CPMV, southern bean mosaic	4, 59

Table 5 Some examples of multiple-disease resistance in dry beans

Cultivars/ lines	Resistant to	Reference
Nairobi Acc. No. 16, 84, 86, 248, 259, 278, 563, 627, 649, 907, 1181	Anthracnose, halo blight, rust	46
Seafarer	BCMV, anthracnose, halo blight	13
Pindak	Rust, Fusarium root rot, curly top virus	57
Laker	Anthracnose, rust	42
C-20	Anthracnose, rust, Fusarium root rot, white mold	42
Swan Valley	BCMV, rust, anthracnose	2
L-226-10	Rust, root rots, ashy stem blight	16

Snyd. & Hans.) are important diseases of pea. Epidemics of downy mildew have been reported from the USSR (18), and pod losses of 60–85% have been reported in an epidemic year (19). Powdery mildew is more serious in tropical than in temperate zones. In a study in India, the loss in pod yield was found to vary from 26–47% in a 100% infected crop (47). In Pakistan, 10–18% yield-loss was recorded (44). Rust can damage the pea crop severely in the submontane regions of northern India. Root rots are important in Europe and the United States (20). Procedures followed for resistance screening have been similar to those used for other foliar and root diseases (20, 45, 53). Combined resistance to powdery mildew and rust has been reported in cultivars C-12 and Wisconsin (45), and in PJ 207508 (53). Cultivar Glacier combines resistance to Ascochyta foot rot (*Ascochyta pinodella* L. K. Jones), and Fusarium wilt (*Fusarium oxysporum* f.sp. *pisi* (Linf.) Snyder and Hansen) (6).

Faba Bean

Chocolate spot (*Botrytis fabae* Sard.; *B. cinerea* Pers.), Ascochyta blight (*Ascochyta fabae* Speg.), and rust (*Uromyces viciae-fabae* (Pers.) Shoet) are reported to be widespread and serious diseases of faba bean. Severe epidemics of chocolate spot have been reported in Syria, Tunisia, and the United Kingdom (22). Ascochyta blight has been reported to be occasionally serious; e.g. an epidemic occurred in Syria in 1976/77 (21). Rust is common throughout the Mediterranean region, and is considered one of the most serious diseases of the faba bean in Egypt. Chocolate spot and rust often occur together, and these have been reported to cause up to 50% yield-loss (28).

ICARDA workers have an active disease-resistance breeding program (S. B. Hanounik, personal communication). They have standardized field procedures to screen for resistance to individual diseases, and efforts are being made to screen for MDR simultaneously. Combined resistance to Ascochyta blight, chocolate spot, and rust has been reported in L 82005, L 82009, and BPL 266, the latter possessing resistance also to Stemphyllium and Alternaria blights (30).

Lentil

Ascochyta blight (*Ascochyta lentis* Bon-Mon. & Vass.), rust (*Uromyces fabae* (Pers.) de Bary), and wilt (*Fusarium oxysporum* f.sp. *lentis* (Vasd. & Srin.) Gord.) are considered serious disease problems of lentil in India, Chile, Ethiopia, and Pakistan (14). Efforts to breed lentils for MDR have been less organized than for other grain legumes. The author worked on lentil diseases in the early 1970s at Pantnagar in northern India and observed wilt and rust resistance in two cultivars, L 9-12 and Bombay 18. Later, another cultivar (Pant L-406) was reported to be resistant to these two diseases (54).

Mungbean

Yellow mosaic (Mungbean Yellow Mosaic Virus-MYMV) and Cercospora leaf spot (*Cercospora canescens* Ell. & Mart.) are the two major disease problems of mungbean. Yellow mosaic is the most devastating disease of mungbean in India (48) and other countries in South Asia (40). Cercospora leaf spot causes severe leaf spotting and defoliation of mungbean in humid tropical areas of Southeast Asia (10, 43, 62). The author could not find any published literature on MDR in mungbean, although resistances to individual diseases have been frequently reported.

CONCLUDING REMARKS

Multiple-disease resistance is not a new concept, but it has assumed importance in recent years because of increased dependence on host-plant resistance in integrated disease-management systems, and also because grain legumes, which provide much-needed protein, are widely grown in developing countries where resources available to farmers are limited. The establishment of IARCs around the world has helped greatly in focusing attention not only on MDR, but also on multiple-stress tolerance (MST) in crop cultivars. We should expect significant progress in the development of MST, including MDR, in grain-legume cultivars around the world by the end of this century.

To assist resource-poor farmers in developing countries in augmenting their incomes, crop scientists must give top priority to ensuring stability of performance of well-adapted, popular local land races, through incorporating MST. Once this is achieved, these farmers would be able to provide the aids such as fertilizers and pesticides that are required to maximize the yields from the crops.

The easy availability of germ plasm is necessary for the improvement of grain legumes. The IARCs and several other institutions are providing such a facility to all national programs. This activity must be allowed to continue and encouraged further in the interest of national grain-legume improvement programs.

Literature Cited

1. Abawi, G. S. 1980. See Ref. 33, pp. 151–56
2. Adams, M. W., Saettler, A. W., Hosfield, G. L., Ghaderi, A., Kelly, J. D., et al. 1986. Registration of Crop cultivars. 69. *Crop Sci.* 26:1080
3. Allen, D. J. 1983. *The Pathology of Tropical Food Legumes*. Chichester: Wiley. 413 pp.
4. Allen, D. J., Emechebe, A. M., Ndimande, B. 1981. Identification of resistance to diseases of the African savannas. *Trop. Agric. (Trinidad)* 58:267–74
5. Asian Vegetable Research and Development Center (AVRDC). 1985. *Progress Report 1983*. Shanhua, Taiwan: AVRDC
6. Auld, D. L., Murray, G. A., Dial, M. J., Crock, J. E., O'Keefe. 1983. Registration of crop cultivars. 12. *Crop Sci.* 23:803
7. Ausemus, E. R. 1943. Breeding for disease resistance in wheat, oats, barley and flax. *Bot. Rev.* 9:207–60
8. Barnes, W. C. 1961. Multiple disease resistant cucumbers. *Proc. Am. Soc. Hort. Sci.* 77:417–23
9. Cabrera de la Colina, J., Trapero-casas, A., Jimenez-Diaz, R. M. 1985. Races of *Fusarium oxysporum* f.sp. *ciceri* in Andalucia, Southern Spain. *Int. Chickpea Newsl.* 13:24–26
10. Catedral, I. G., Lantican, R. M. 1978. Mungbean breeding program of UPLB, Philippines, *Proc. 1st Int. Mungbean Symp., Los Banos*, pp. 225–27. Taiwan: AVRDC
11. Centro Internacional de Agricultura Tropical (CIAT). 1985. *Annual Report 1984*. Cali, Colombia: CIAT
12. Consultative Group on International Agriculture (CGIAR). 1986. *Annual Report 1985*. Washington, DC: CGIAR
13. Conway, J., Hardwick, R. C., Innes, N. L., Taylor, J. D., Walkey, D. G. A. 1982. White-seeded beans *(Phaseolus vulgaris)* resistant to halo blight *(Pseudomonas phaseolicola)*, to bean common mosaic virus, and to anthracnose *(Colletotrichum lindemuthianum)*. *J. Agric. Sci.* 99:555–60
14. Erskine, W. 1985. Perspectives in lentil breeding. In *Proc. Int. Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s*, pp. 91–100. Saxena, Varma, Aleppo, Syria: ICARDA
15. Food and Agriculture Organization of the United Nations (FAO). 1976. *Production Year Book*. 28.1:325
16. Freytag, G. F., Kelly, J. D., Adams, M. W., Lopez Rosa, J., Beaver, J., et al. 1985. Registration of Germplasm, GP.51. *Crop Sci.* 25:714
17. Gaskill, J. O., Mumford, D. L., Ruppel, E. G. 1970. Preliminary report on breeding for combined resistance to leaf spot, curly top, and *Rhizoctonia*. *J. Am. Soc. Sugar Beet Technol.* 16:207–13
18. Golubev, A. A., Yankov, I. I. 1979. Peronospora epiphytotics on pea. *Zashchita Rastenii*. 7:41–42
19. Hagedorn, D. J. 1973. Peas. In *Breeding Plants for Disease Resistance: Concepts and Applications*, ed. R. R. Nelson, pp. 326–43. University Park & London: Pa. State Univ. Press
20. Hagedorn, D. J. 1980. See Ref. 33, pp. 143–50
21. Hanounik, S. B. 1979. Diseases of major food legume crops in Syria. In *Food Legume Improvement and Development*, ed. G. C. Hawtin, C. J. Chancellor, pp. 98–102. Ottawa: IDRC
22. Hanounik, S. B., Hawtin, G. C. 1982. Screening for resistance to chocolate spot caused by *Botrytis fabae*. In *Faba Bean Improvement*, ed. G. C. Hawtin, C. Webb, pp. 243–50. The Hague: Martinus Nijhoff
23. Hapgood, F. 1987. Soybean. *Natl. Geogr. Mag.* 172:66–91
24. Hartwig, E. E. 1975. Breeding soybeans resistant to diseases. *Workshop on Grain Legumes*, pp. 305–10: Patancheru, A. P., India: ICRISAT
25. Deleted in proof

26. Haware, M. P., Nene, Y. L. 1982. Races of *Fusarium oxysporum*, f.sp. *ciceri*. *Plant Dis*. 66:809–10
27. Hubbeling, N. 1957. New aspects of breeding for disease resistance in beans (*Phaseolus vulgaris* L). *Euphytica* 6:111–41
28. Ibrahim, A. A., Nassib, A. M., El-Sherbeeny, M. 1979. Production and improvement of grain legumes in Egypt. See Ref. 21, pp. 39–41
29. International Center for Agricultural Research in the Dry Areas (ICARDA). 1985. *Annual Report 1984*. Aleppo, Syria: ICARDA
30. International Center for Agricultural Research in the Dry Areas (ICARDA). 1985. *Research Highlights 1984*, pp. 14–15. Aleppo, Syria: ICARDA
31. International Center for Agricultural Research in the Dry Areas (ICARDA). 1986. *Annual Report 1985*. Aleppo, Syria: ICARDA
32. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1975. *Proc. Int. Workshop Grain Legumes*. Hyderabad: ICRISAT. 350 pp.
33. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1980. *Proc. Consultants' Group Discussion on the Resistance to Soil-borne Diseases of Legumes, 1979*, ed. Y. L. Nene. Patancheru, A.P. 502 324, India: ICRISAT. 167 pp.
34. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1981. *Annual Report 1979/80*. Patancheru, A.P., India: ICRISAT
35. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1981. *Proc. Int. Workshop on Pigeonpeas*. 1:508
36. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1984. *Annual Report 1983*. Patancheru, A.P. 502 324, India: ICRISAT
37. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1986. *Annual Report 1985*. Patancheru, A.P. 502 324, India: ICRISAT
38. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1987. *Annual Report 1986*. Patancheru, A.P. 502 324, India: ICRISAT
39. International Institute of Tropical Research (IITA). 1985. *Annual Report 1984*. Ibadan, Nigeria: IITA
40. Iwaki, M., Auzay, H. 1978. Virus diseases of mungbean in Indonesia. See Ref. 10, pp. 169–72
41. Kannaiyan, J., Nene, Y. L., Reddy, M. V., Ryan, J. G., Raju, T. N. 1984. Prevalence of pigeonpea diseases and associated crop losses in Asia, Africa, and the Americas. *Trop. Pest Manage*. 30:62–71
42. Kelly, J. D., Adams, M. W., Saettler, A. W., Hosfield, G. L., Ghaderi, A. 1984. Registration of crop cultivars no. 43. *Crop Sci*. 24:822
43. Legaspi, B. M., Catipon, E. M., Hubbel, J. N. 1978. AVRDC Philippine outreach program mungbean studies. See Ref. 10, pp. 220–23
44. Mahmood, T., Ahmad, I., Qureshi, S. H., Aslam, M. 1983. Estimation of yield losses due to powdery mildew in peas. *Pak. J. Bot*. 15:113–15
45. Mahrshi, R. P., Gupta, R. B. L., Mathur, A. K. 1982. Response of pea varieties to powdery mildew and rust in Rajasthan. *Indian Phytopathol*. 35:232–35
46. Mukunya, D. M., Keya, S. O. 1978. Yield performance and selection for resistance in beans (*Phaseolus vulgaris* L.) to common diseases in Kenya. *East Afr. Agric. For. J*. 43:392–98
47. Munjal, R. L., Chenulu, V. V., Hora, T. S. 1963. Assessment of losses due to powdery mildew *(Erysiphe polygoni)* on pea. *Indian Phytopathol*. 35:111–14
48. Nene, Y. L. 1973. Viral disease of some warm weather pulse crops in India. *Plant Dis. Reptr*. 57:463–67
49. Nene, Y. L. 1982. The outlook for chickpea and pigeonpea. *SPAN* 25:14–16
50. Nene, Y. L., Kannaiyan, J., Reddy, M. V. 1981. *Information Bulletin* 9, Patancheru, A.P. 502 324, India: ICRISAT
51. Nene, Y. L., Sheila, V. K., Sharma, S. B. 1984. *Pulse Pathology Prog. Rep*. 32:1–19. Patancheru 502 324 India: ICRISAT
52. Orton, W. A. 1902. The wilt disease of the cowpea and its control. *US Dep. Agric. Bur. Plant Industries Bull*. 17:9–20
53. Pal, A. B., Brahmappa, Rawal, R. D., Ullasa, B. A. 1980. Field Resistance of pea germplasm to powdery mildew *(Erysiphe polygoni)* and rust *(Uromyces fabae)*. *Plant Dis*. 64:1085–86
54. Pandya, B. P., Pandey, M. P., Singh, J. P. 1980. Development of Pant-L-406, resistant to rust and wilt. *Lens* 7:34–37
55. Reddy, M. V., Singh, K. B. 1984. Evaluation of a world collection of chickpea germplasm accessions for resistance to Ascochyta blight. *Plant Dis*. 68:900–1
56. Rodriguez, R., Melendez, P. L. 1984. Field screening of pigeonpea *(Cajanus*

cajan) for resistance to foliar diseases in Puerto Rico. *J. Agric. Univ. Puerto Rico* 68:275–79
57. Schneiter, A. A., Bruke, D. W., Venette, J. R. 1982. Registration of crop cultivars 23. *Crop Sci.* 22:156
58. Schwartz, H. F., Galvez, G. E., eds. 1980. *Bean Production Problems: Disease, Insect, Soil and Climatic Constraints of Phaseolus vulgaris*. Cali, Colombia: CIAT
59. Sheoraj, P., Patel, P. N. 1977. Studies on resistance in crops to bacterial disease in India. 9: sources of multiple disease resistance in cowpea. *Indian Phytopathol.* 30:207–12
60. Singh, B. B., Ntare, B. R. 1985. Development of improved cowpea varieties in Africa. See Ref. 61, pp. 105–16
61. Singh, S. R., Rachie, K. O., eds. 1985. *Cowpea Research, Production and Utilization*. Chichester: Wiley. 460 pp.
62. Somaatmadja, S., Sutarman, T. 1978. Present status of mungbean breeding in Indonesia. See Ref. 10, pp. 230–32
63. United States Department of Agriculture. 1953. *Plant Diseases, the Yearbook of Agriculture*. 940 pp.
64. Webber, H. J., Orton, W. A. 1902. A cowpea resistant to root-knot *(Heterodera radicicola). US Dep. Agric. Bur. Plant Industries Bull.* 17:23–26
65. Williams, P. H., Walker, J. C., Pound, G. S. 1968. Hybelle and Sanibel, multiple disease-resistant F1 hybrid cabbages. *Phytopathology* 58:791–96