Seed-transmitted pests and diseases of legumes in rice-based cropping systems

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The paper gives an overview of the seedborne pests and diseases of soybean, cowpea, green gram, chickpea, pigeonpea, and peanut, which can all be used in rotation with rice. Insect pests, nematodes, and diseases of common occurrence, potentially important ones that can occasionally become serious, and those that cause great economic losses are listed. The distribution of pests and diseases is also given, along with the rate of seed transmission of important virus diseases and data on crop losses. Safeguards are discussed to check the spread of pests and diseases that can be introduced through exchange of legume seeds, thus countering any benefit likely to be derived from a legume - rice rotation.

Legumes form a very important component of a rice-based cropping pattern in the potentially most productive farming system in the tropics. The important grain legume crops used in rotation with rice are soybean (*Glycine max* [L.] Merr.), cowpea (*Vigna unguiculata* [L.] Walp.), green gram (*Vigna radiata* [L.] Wilczek), chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* [L.] Millsp.), and peanut (*Arachis hypogaea* L.). Dovetailing these crops with rice has great potential, as evident from the cropping systems research results at the International Rice Research Institute (IRRI) (IRRI 1983).

The spread of some of the economically important crop pests and diseases is linked with the movement of seeds, which act as their carriers within a country and across national frontiers. Because 90% of all food crops grown in the world are propagated through seed (Neergaard 1979), it is essential for us to know which pests and diseases are likely to be transmitted through the seed, and their world distribution, so that appropriate plant quarantine measures can be taken.

The seeds of legume crops are important carriers of insect pests, fungi, bacteria, and viruses. Together or singly, some of the pests and pathogens constitute a serious threat to the cultivation of legume crops and therefore will affect the use of legumes in a rice-based cropping system. Exotic pests and diseases present a greater hazard than local pests and pathogens to crop breeding and plant introduction programs.

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This paper deals with the major seedborne pests and diseases of legume crops that can be used in rotation with rice, their distribution, economic importance, and control.

INSECT PESTS

Of the insect pests that attack legumes, beetles belonging to the family Bruchidae are important. Bruchids are essentially storage pests, but infestation by some species starts in the field when a crop is nearing maturity. The adults do not damage the seed. They lay eggs singly on the seed surface. The eggs are visible to the naked eye, and the larvae bore inside the cotyledons on hatching. The larvae are internal feeders; their damage to the cotyledons and sometimes to the embryo constitutes a serious germination problem in addition to creating storage losses. The important species recorded as damaging and breeding on dry seed are given in Table 1.

In pulses, *Callosobruchus maculatus* and *C. chinensis* are the most common and destructive pests of dried seed in Asia. The two species attack more than 14 economically important legume seeds worldwide. *C. phaseoli* is a relatively less known species as far as economic damage is concerned, but Southgate (1978) considers it a dominant species in tropical South America. In India, *C. analis* prefers to attack green gram, although it occurs in association with *C. chinensis*. *C. rhodesianus* is an important storage pest of cowpea in Africa, and its spread beyond that continent would be serious. Pigeonpea is attacked by the largest number of bruchids. *C. theobromae* and *C. dolichosi* are confined to the Indian subcontinent

Table 1. Important insect pests recorded on some legume seeds and their distribution.

Crop	Insect species	Distribution
Chickpea, pigeonpea, cowpea, green gram, soybean	*Callosobruchus chinensis, C. maculatus*	Worldwide
Cowpea, pigeonpea, green gram	*Callosobruchus phaseoli.*	Asia, Africa, Europe, USSR Philippines, West Indies
	C. analis	Brazil, Asia, Africa, Europ Australia, Indonesia, Japa Hong Kong, Malaysia, Philippines
Cowpea	*C. rhodesianus*	West Africa, Nigeria, Uganda, Kenya, Tanzani South Africa
	Bruchidius atrolineatus	Nigeria
	Specularis erythraeus	Kenya
Pigeonpea	*C. theobromae*	India, Sri Lanka
	C. dolichosi	India, Burma
	Acanthoscelides zeteki	Caribbean Islands, Centr and South America
	Specularis sulcaticollis	Kenya
	S. erythraeus	Nigeria, Kenya
Peanut	*Caryedon serratus*	Asia, Africa, Middle Ea Israel, Mexico, South America, West Indies, Taiwan, Thailand

but the extent of their damage is not well known. However, infestation with *Acanthoscelides zeteki* has been recorded to reach 40% in storage (Southgate 1979) in the Caribbean Islands, while *Specularis sulcaticollis* and *S. erythraeus* are lesser known species, but their association with pigeonpea seeds cannot be ignored.

Caryedon serratus is a major pest of stored peanut, causing considerable damage to undecorticated and decorticated nuts. Unlike other bruchids, which infest stored legumes, the full-grown grub leaves the seed or pod after cutting an exit hole and pupates outside in a papery cocoon. Other insects associated with peanut kernels are *Tribolium castaneum, Oryzaephilus surinamensis, O. mercator, Ephestia cautella,* and *Corcyra cephalonica.* They are cosmopolitan and are therefore not considered serious quarantine hazards. They may, however, carry pathogenic seedborne fungi (Majumder et al 1973) that could be dangerous.

NEMATODES

Seedborne nematodes are very rare in legume seeds. There are only two species of nematodes – the lesion nematode (*Pratylenchus brachyurus*) and the testa nematode (*Aphelenchoides arachidis*) – recorded on peanut pods or seeds from Australia, Africa, Egypt, USA, and Nigeria, and one species – the soybean cyst nematode (*Heterodera glycines*) – on soybean seeds from Egypt, USA, and Japan.

The lesion nematode is a major pest of peanut in the USA. It is found in the roots, pegs, and shells of mature pods but has never been reported in the seeds. Hundreds of nematodes may be present in each dark-colored necrotic lesion on the shells. Their importance is heightened by their association with *Sclerotium rolfsii,* the fungus responsible for peg rot (Minton 1984).

The testa nematode is a facultative endoparasite that is present in numbers up to 25,000 within the tissue of the shell or seed testa. Its presence predisposes the seed to invasion by soil fungi (Table 2).

Seeds of soybean carry cysts of the soybean cyst nematode, either loose or mixed with soil. The losses caused by *H. glycines* have not yet been quantified but may be significant (Epps 1969).

DISEASES

It is considered safer to use seeds than vegetative plant propagules to transfer plant material (Asia and Pacific Plant Protection Commission 1980, Phatak 1981). Nevertheless, there are many seedborne diseases, particularly viruses, in legumes, some of which are classified as dangerous to the crops. The major seedborne diseases of legume crops are given in Tables 2-5.

Soybean

Soybean seeds are associated with many fungal pathogens (Table 4), which deteriorate seeds and impair their viability. Heavy infections of stem canker (*Diaporthe phaseolorum* var. *batatatis*) have resulted in considerable yield losses in Canada (Wallen and Seaman 1962). Dunleavy (1956) reported a 65% field incidence

Table 2. Seed-transmitted soilborne fungal diseases of some important legumes.

Species	Diseases	Crops[a]	Distribution
Fusarium spp.	Root rot	Gm	Worldwide
F. solani	Collar rot	Vu, Vr, Ca	Worldwide
F. equiseti	Wilt	Vu, Vr	Worldwide
F. semitectum	Wilt	Vu, Vr, Cc	Worldwide
F. oxysporum f. sp. *tracheiphilum*	Wilt	Gm	USA, Europe, India
		Vu	USA, Brazil, Africa, Malaysia, Thailand, Australia, India
F. oxysporum f. sp. *ciceri*	Wilt	Ca	Asia, Africa, Mexico, Middle East, USA, South America
F. oxysporum f. sp. *udum* (=*F. udum*)	Wilt	Cc	Asia, Africa, Mauritius, Trinidad
Macrophomina phaseolina	Ashy stem blight, charcoal rot, seedling rot	Gm, Vu, Vr, Ah	Worldwide
Pythium aphanidermatum	Seed decay, seedling mortality, stem rot	Vu	Nigeria, Tanzania, Brazil
Rhizoctonia bataticola	Dry root rot	Ca	Asia, Australia, Ethiopia, Middle East, USA, Turkey
		Cc	India, Jamaica
R. solani	Damping off, foot and basal stem rot	Gm, Vr, Ah	Worldwide
	Web blight	Vu, Gm	Worldwide
Sclerotium rolfsii	Stem rot	Gm, Vu, Ah	Worldwide
Myrothecium roridum	Collar rot	Vr	India
Sclerotinia sclerotiorum	Stem rot	Gm, Ca	Worldwide

[a]Gm = *Glycine max*, Vu = *Vigna unguiculata*, Vr = *Vigna radiata*, Ca = *Cicer arietinum*, Cc = *Cajanus cajan*, Ah = *Arachis hypogaea*.

of pod and stem blight (*D. phaseolorum* var. *sojae*) in Iowa, USA. In Brazil, the latter pathogen has also rendered sensitive cultivars unsuitable for cultivation (Bolkan et al 1976). Among the foliar diseases, frog eye leaf spot (*Cercospora sojina*) and brown spot (*Septoria glycines*) have caused 15 and 17.9% crop losses, respectively, in the USA; and web blight (*Rhizoctonia solani*) produced 80% crop infection in China (Allen 1983, Williams and Nyvall 1980).

Bacterial blight caused by *Pseudomonas syringae* pv. *glycinea* inhibited germination of soybean seed by 68% in the USA (Sinclair 1975); similar results were obtained in India (Nicholson et al 1973). In the USA, this disease caused great monetary loss in Iowa (Kennedy and Alcorn 1980), but the crop loss due to bacterial pustule caused by *Xanthomonas campestris* was 15% (Laviolette et al 1970). According to Watson (1970), *P. syringae* pv. *glycinea* was introduced into New Zealand through infected seed.

Of the viruses, soybean mosaic virus (SMV) is the most serious and widespread. It has reduced yield by 9-20% in Bulgaria (Bov and Boyadzhiev 1977) and by 20% in

Table 3. Seed-transmitted viruses of major importance in some legume crops.

Virus	Distribution	Transmission (%)	Reference
	Soybean		
Cowpea mild mottle virus	Ghana, Ivory Coast, Thailand, Argentina	<91.7	Allen (1983)
Soybean mosaic virus	India, Korea, China, USA, Canada, France	0.05-10.2	Goodman and Oard (1980)
	Bulgaria, USSR, Brazil, Nigeria, Lebanon, Iran	10.6 -29.1	Suteri (1981)
Tobacco ring spot virus	USA, Canada, Africa, China, Australia	100	Iizuka (1973)
	Cowpea		
Cowpea severe mosaic virus	South America	10	Singh and Allen (1980)
Cowpea aphid-borne mosaic virus	Widespread	0-40	Singh and Allen (1980)
Cowpea mottle virus	Nigeria	3-10	Singh and Allen (1980)
Cowpea banding mosaic virus	India	9-34	Prakash and Joshi (1980)
Cowpea chlorotic spot	Worldwide	4-20	Singh and Allen (1980)
Blackeye cowpea mosaic virus	USA, Brazil, India	13	Zettler and Evans (1973)
Cowpea yellow mosaic virus	America, Africa	1-5	Allen (1983)
	Green gram		
Bean common mosaic virus	Iran, India	8-32	Kaiser and Mossahebi (1974)
	Peanut		
Peanut mottle virus	Worldwide	0-8.5	Kuhn and Demski (1984)
Peanut clump virus	India, West Africa	4-14	Thouvenel et al (1978)
Peanut stunt virus	USA, Europe, Morocco, Japan	0.0073-0.207	Tolin (1984)
Marginal chlorosis virus	New Guinea	71	Van Velsen (1961)
Peanut stripe virus	North America, China, Indonesia, Malaysia, Philippines, Thailand	19.3-37.6	Demski et al (1984a)

Table 4. Seed-transmitted fungal and bacterial diseases of soybean with a worldwide dis bution.

Pathogen	Diseases	Seed transmission (%)	Reference
Cercospora kikuchii	Purple blotch, purple speck, purple seed stain		-
Colletotrichum truncatum	Seedling blight, anthracnose	15-81	Verma and Upadhy (1973)
Diaporthe phaseolorum var. *batatatis*	Stem canker, pod and stem blight		
D. phaseolorum var. *sojae* (con. st. *Phomopsis*)	Pod and stem blight	20	Wilcox and Abney (1971)
Peronospora manshurica	Downy mildew		
Pseudomonas syringae pv. *glycinea*	Bacterial blight	3-64	Nicholson and Sinc (1971)
Xanthomonas campestris pv. *glycines*	Bacterial pustule		

the USA (Ross 1977), and germination by 12-36% in India (Sutheri 1981). The vi. predisposes seed to infection by *Phomopsis sojae* (Hepperly et al 1979). Tobacc ring spot virus (TRSV) impairs seed viability and may also reduce yield by 50 (Crittenden et al 1966), the crop loss depending on the percentage of incidence i seed (Allen 1983). TRSV also infects green gram (Allen 1983, Shivanathan 1979 Cowpea mild mottle virus (CMMV), although a minor disease in cowpea, has bee found serious in soybean in Thailand (Brunt and Phillips 1978) and the Ivory Coa (Thouvenel et al 1982), and it appears to be of considerable importance in tropic soybean.

Cowpea

Ascochyta leaf spot (*Ascochyta phaseolorum*) is potentially the most destructi disease of cowpea in Africa, causing severe losses in cooler regions (Williams 197 In Nigeria, a 75% crop loss due to *R. solani* and *Pythium aphanidermatum* se infection, a 35-50% yield loss due to anthracnose (*Colletotrichum lindemuthianun* and 50% seedling mortality due to wilt (*Fusarium oxysporum* f. sp. *tracheiphilu* were reported (Allen 1983, Singh and Allen 1980). Wilt was responsible for 7 mortality in India (Singh and Sinha 1955). Emechebe and McDonald (1979) a Emechebe (1981) also reported serious cowpea diseases in Nigeria caused by *capsici, C. truncatum*, and *Macrophomina phaseolina*.

In India, bacterial blight of cowpea caused by *Xanthomonas vignicola* v responsible for considerable seedling mortality, and 62% disease incidence v observed with an initial seed inoculum of only 1% (Shekhawat and Patel 1977).

There are more than 16 seedborne viruses of cowpea, some of which have hi transmission rates and cause more than 50% yield loss in the field. Cowpea aph borne mosaic virus (CAMV) was responsible for complete loss of the crop in Nige in 1973 (Raheja and Leleji 1974). Other serious, internationally important vi diseases in tropical America, East Africa, and West Africa reported by Allen (19

Table 5. Important seed-transmitted foliar fungal and bacterial diseases of some legumes.

Pathogen	Diseases	Distribution
	Soybean	
Cercospora sojina	Frog eye leaf spot	Asia, Guatemala, Venezuela, Brazil, USA, Canada, Cameroon, Europe, USSR, Australia
Septoria glycines	Brown spot	Widespread
	Cowpea	
Ascochyta phaseolorum	Leaf spot	Central and South Africa, Asia
Colletotrichum capsici and *C. truncatum*	Brown blotch	Nigeria
C. lindemuthianum	Anthracnose	Africa, India, Brazil
Xanthomonas campestris pv. *vignicola*	Bacterial blight, bacterial canker	USA, Puerto Rico, Brazil, India, Africa
	Green gram	
C. capsici, C. truncatum	Anthracnose	India
Elsinoe phaseoli	Scab	America, Zimbabwe, Brazil
Pseudomonas syringae pv. *phaseolicola*	Halo blight	USA, Europe
inthomonas campestris pv. *haseoli* (fuscans)	Fuscous blight	India
	Chickpea	
scochyta rabiei	Blight	North Africa, West Asia, Australia, Canada, Mexico, Europe, Middle East, Turkey, USSR
trytis cinerea	Grey mold	Argentina, Colombia, Canada, USA, Spain, Asia, Australia
	Pigeonpea	
ioma sp.	Stem canker	Puerto Rico, Trinidad
iomopsis sp.	Seedling rot	Puerto Rico
tryodiplodia theobromae	Seedling rot	Puerto Rico
illetotrichum cajani	Anthracnose	Puerto Rico, Hawaii, India, Brazil
inthomonas cajani	Bacterial leaf blight	India, Panama, Sudan
	Peanut	
eudomonas solanacearum	Bacterial wilt	Indonesia, Africa, Japan, USA, China

e cowpea severe mosaic virus (CSMV), cowpea yellow mosaic virus (CYMV), and wpea mottle virus (CMV), which have caused yield losses up to 80%, 95%, and %, respectively. In India, the field incidence of cowpea banding mosaic virus BMV) and cowpea chlorotic spot (CCS) varied from 13 to 62%, which reduced e yield up to 41.8% (Sharma and Varma 1975), while in Nigeria, CCS caused a % loss (Singh and Allen 1980). More than one virus may occur in cowpea. A ixture of cucumber mosaic virus and blackeye cowpea mosaic virus leads to nergism (Pio-Ribeiro et al 1978) and to consequent stunting and severe crop loss.

reen gram

edborne pathogens encountered on green gram (Table 2, 5) are responsible for eemergence and postemergence diseases leading to loss of stand. The bacterial halo blight disease caused by *Pseudomonas phaseolicola* spreads very rapidly and i widely distributed on beans (*Phaseolus vulgaris*) in temperate regions of the world A mungbean strain of *P. phaseolicola* introduced with seed in Ohio, USA, caused 60% yield reduction (Schmitthenner et al 1971). Because halo blight disease ca initiate epidemics at a very low level (0.01%) of seed contamination in French bea (Taylor and Dudley 1977) and is transmissible through green gram seed, it can b characterized as a very dangerous pathogen of great quarantine significanc Another important disease of green gram is bean common mosaic virus (BCMV which reduced yields by 31-75% in Iran (Kaiser and Mossahebi 1974).

Chickpea

Ascochyta blight (*Ascochyta rabiei*) and wilt (*Fusarium oxysporum* f. sp. *ciceri*) are two major seedborne diseases of chickpea. *A. rabiei* has been responsible for severe epidemics in Pakistan, Bulgaria, USSR, and Greece (Nene 1982), the extent of crop loss varying between 20 and 100%; it caused a severe epidemic in the chickpea crop in Canada in 1973, where the pathogen was introduced through imported seed (Morrall and McKenzi 1974). Chickpea wilt caused a 10% crop loss in Uttar Pradesh, India (Mathur et al 1960), while Haware and Nene (1980) found a 24-94% yield loss depending on the crop growth stage during attack.

Pigeonpea

Pigeonpea wilt (*Fusarium udum*) is the most destructive seedborne disease of pigeonpea in India and East Africa. Continuous cropping in the same field may lead to 50% or more plant mortality due to wilt (Sen Gupta 1974). *Rhizoctonia bataticola* in India and *Phoma* sp., *Phomopsis* sp., *Botryodiplodia theobromae*, and *Fusarium semitectum* in Puerto Rico and the Caribbean Islands are serious pathogens of pigeonpea that affect germination in the field. Pigeonpea anthracnose (*Colletotrichum cajani*) is a common disease in Puerto Rico, and as early as 1927 Tucker reported a 36% loss in yield from 87% infected pods.

Peanut

Peanut seeds are affected by several important diseases. Ashworth et al (1961) reported extensive damage by seedborne *Sclerotium rolfsii* and *R. solani*; the former was responsible for 10% diseased pods in the infected plants, and the latter reduced seedling emergence by 30% and yield by 25% in the USA.

Of the virus diseases, peanut mottle virus (PMV) is the most widely distributed and serious seedborne peanut virus in the world. In some areas, 75-90% of the crop can be infected (Paguio and Kuhn 1973), causing a yield loss as high as 30% (Kuhn and Demski 1975). In Georgia, USA, a 5-6% economic loss was estimated from 26% infected plants in 1 yr (Kuhn and Demski 1984)—calculated at US$11 million in 1973 (Smith 1980). PMV can also be transmitted to soybean (Demski 1975) through an infected peanut crop. Peanut clump virus (PCV) has been observed to reduce yield by 60% in India (Nolt and Reddy 1984), and marginal chlorosis (MCV) by 50% in New Guinea (Van Velsen 1961). Peanut stunt virus (PSV) has a very low seed transmission rate (0.2%), but 70-80% crop losses might occur in the USA (Culp and Troutman 1967), and the disease could be a serious threat to peanut production. A newly reported peanut stripe virus (PStV) may cause yield losses up to 23% in the early stages of infection (Demski et al 1984a, Demski and Lovell 1985). The virus was isolated from peanut germplasm lines introduced into the USA from China (Demski et al 1984b). The crop losses caused by various peanut viruses cannot be correlated with the infection rate in seed: PSV, with a very low rate of seed transmission, can cause heavy crop losses, but PStV, with high seed incidence, may cause relatively less damage.

DISCUSSION

Insect pests of legumes do not pose a large hazard if seed is fumigated. The danger could come from the spread of economically important species, such as *Callosobruchus rhodesianus* from Africa and *Caryedon serratus* from the Indian subcontinent, to new areas. However, detection of latent infestation of bruchids inside the seeds by X-ray techniques, and fumigation with methyl bromide at 32 g/m^3 for 4 h under vacuum can control the pests effectively (Varma 1985). Fumigation may not be effective for the control of peanut and soybean nematodes without endangering seed viability. Instead, importation of peanut as kernels rather than pods, and selection of healthy, mature, clean seed from nematode-free areas would assist efforts to prevent the spread of these pests.

Seedborne diseases are more refractory than pests. Soybean viruses CMMV and TRSV, and bacterial pustule are restricted in distribution, and their dissemination could be checked through strict regulatory measures. As an additional safeguard, a growing-on test of imported seed in an insect-proof screenhouse could be followed whenever necessary.

The role of seed treatment in the control of soybean diseases is not very conclusive. Nevertheless, the use of a thiram + benomyl mixture or chloranil can control some of the fungal diseases and improve germination to a great extent (Agarwal 1981, Neergaard 1979).

The seedborne diseases of cowpea, particularly anthracnose and the viruses, provide a major production constraint. The widespread occurrence of CAMV is reflected in its seed transmissibility, and there is every possibility of CSMV, CMV, CBMV, and CYMV finding their way to other countries through seed exchange unless plant quarantine measures, e.g., pre-export inspection of crops, and growing-on tests in the importing country, are rigorously enforced. Unfortunately, chemical seed treatment of cowpea has not been found very effective against major diseases, and therefore the use of resistant lines may be necessary.

In contrast to soybean and cowpea, green gram seed carries fewer pathogens of a serious nature. Halo blight is confined to the temperate regions, and BCMV has very limited distribution in the tropics. Since most world green gram production is in the Indian subcontinent, it would be prudent to check the introduction and spread of these two diseases in Asia. However, halo blight can be controlled by treating the seed with streptomycin or kasugamycin (Taylor and Dudley 1977), which should be required.

Vascular wilt and Ascochyta blight are the most important chickpea diseases causing substantial crop losses. Fortunately, seedborne inocula of these two diseases can be effectively controlled by seed treatment with systemic fungicides. Thiobendazole, tridemorph, and thiram + benomyl have been found very effective in controlling the seedborne inocula of Ascochyta blight, Botrytis grey mold (Grewal 1982, Reddy 1980, Reddy and Kababeh 1984), and Fusarium wilt (Haware et al 1978); they can be used to disinfect the seed. Similarly, the spread of pigeonpea wilt can be checked through seed treatment with captan (Ellis et al 1977) or a thiram + benomyl mixture (Kannaiyan et al 1980).

Bacterial wilt caused by *Pseudomonas solanacearum* is a potential seedborne disease of peanut in wet soil. Darong et al (1981) reported a 30% loss in China. Strict control of seed movement should be enforced to avoid the spread of the pathogen to disease-free areas.

Peanut viruses PCV, PSV, MCV, and PStV have restricted distribution and because of their great economic importance, their spread needs to be checked. Peanut seeds must be grown in virus-free areas reinforced by enzyme-linked immunosorbent assay tests for making healthy virus-free seeds available.

CONCLUSION

Given the spectrum of seedborne pests and diseases of these legume crops, seeds of soybean, cowpea, peanut, and green gram constitute a quarantine risk and need controlled introduction. Importing countries can avoid introducing seedborne viruses and bacteria of these crops by importing healthy seed covered by a certificate of seed quality and by a growing-on test in an insect-proof screenhouse. Chickpea and pigeonpea seeds are relatively safer to import if they have had the prescribed seed treatment, which can eliminate the risk of seedborne diseases.

Seed certification in the country of origin, fumigation upon arrival, careful inspection combined with chemical treatment, and postentry quarantine whenever necessary are reasonable safeguards for the import of soybean, cowpea, peanut, and green gram and should be followed.

Fortunately, there are no common seedborne pathogens of legumes and rice, so that growing a legume crop before or after rice should be safe. Nevertheless, the economic efficiency of a legume - rice rotation will depend on the extent to which the legume crop is exposed to the risk of pests and diseases. If the research and development needs of leguminous crops could be met by breeding cultivars resistant to major economic diseases, then it should be possible to achieve a major breakthrough in organizing a more efficient legume-based cropping system in rice without danger from introduced pests or diseases.

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