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A field guide for identification and scoring methods of diseases in the mountain crops of Nepal

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This publication is prepared for the UNEP/GEF supported project "Integrating Traditional Crop Genetic Diversity into Technology: Using a Biodiversity Portfolio Approach to Buffer against Unpredictable Environmental Change in the Nepal Himalayas". The project is coordinated by the Bioversity International in collaboration with Nepal Agricultural Research Council (NARC), Department of Agriculture (DoA) and Local Initiatives for Biodiversity, Research and Development (LI-BIRD).

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Bioversity International is a member of the CGIAR Consortium, a global research partnership for a food-secure future.

www.bioversityinternational.org

Published By
Bioversiy International
93.4 Dharahara Marg, Fulbari-11
Pokhara, Nepal

ISBN 978-92-9255-052-3

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Citation: Manandhar, H.K., Timila, R.D., Sharma, S., Joshi, S., Manandhar, S., Gurung, S.B., Sthapit, S., Palikhey, E., Pandey, A., Joshi, B.K., Manandhar, G., Gauchan, D., Jarvis, D.I. and Sthapit, B.R. 2016. A field guide for identification and scoring methods of diseases in the mountain crops of Nepal. NARC, DoA, LI-BIRD and Bioversity International, Nepal.

Cover photos: H.K. Manandhar, S.B. Gurung, A.R. Adhikari

Cover and interior design: Amrit Gurung

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Acknowledgements

The preparation of this guide would not have been possible without the cooperation and support of several people, including: Mr. Ratna Upadhyaya, Ms. Srijana Poudel and Ms. Damali Sherpa at the project site in Jumla; Mr. Nawa Raj Bhatta at the Agriculture Research Station of NARC, Jumla; Mr. Anish Subedi and his group, including Ms. Hira Devi Hamal and Ms. Bimala Singh Shahi, at the project site in Humla; and Ms. Rita Gurung, Mr. Sriram Subedi and Mr. Ajay Gurung at the project site in Lamjung.

Special thanks and appreciations are given to Professor Timothy Daniel Murray, Washington State University, USA, for his contribution to the reviewing and editing of this guide. Prof. Murray's thorough corrections have made this guide more practical. Additionally we would like to recognise Ms Rose Nankya, Bioversity-Uganda and Dr. Giovanna Plata, PROINPA-Bolivia, for going through the draft and providing their valuable comments and suggestions.

Sincere thanks are due to Ms. Deepa Singh Shrestha at the Gene Bank, NARC for her contribution to the section on bean diseases.

Mrs. Richa Gurung and Mr. Alexander Byrnes, Bioversity-Nepal; and Mr. Safal Khatiwada at the GEF project office, Gene Bank are greatly acknowledged for their kind cooperation, support and facilitation during the preparation of this guide. Mr. Amrit Gurung is gratefully acknowledged for his excellent cover and guide design.

Contents

About the Guide

This guide is a compilation of published information for the identification and scoring of diseases of selected mountain crops (amaranth, barley, beans, buckwheat, finger millet, foxtail millet, proso millet and rice) in Nepal. As this guide is intended for the crops grown in the mountain region, it does not cover all the diseases known to occur in the country. Also, disease information on some of the crops, especially proso millet, foxtail millet, buckwheat and grain amaranth, is very limited. As a result, the disease information of these crops might not have been sufficiently covered in this guide. Some of the diseases included in this guide have not been reported in Nepal, but they are included because of their likely occurrence in the mountain climates.

For identification purposes, pictures of pathogens and disease symptoms have been derived from different sources. Also, several pictures, especially of disease symptoms, taken during field visits to the project sites in Jumla, Humla, Lamjung and Dolkha have been used. Several diseases were diagnosed at the Plant Pathology Division of Nepal Agricultural Research Council, Khumaltar, Lalitpur.

The scoring scales for various diseases have been taken from different sources; for example, the IRRI scale for rice diseases, the CIMMYT scale for barley, the CIAT scale for beans, and other scales published by various researchers for other crops. Scoring scales for disease assessment vary a lot. Specific disease scoring scales are not available for some crops. In such cases, scoring scales describing similar diseases were adopted from other crops.

One can note that some scales start with '0' while others begin with '1'. In this guide, the starting value for most of the bean diseases is '1' for no disease, and for most of the other crops it is '0'. Generally, '0' values are disregarded for statistical analysis, but it depends how the value is used for analysis. While it was

proposed to simply change all the values of '0' to '1', this was not done, as it would be inappropriate to modify the widely adopted international scales.

This guide is primarily based on one season of field verification of the crops. It is hoped that the Guide will be revised and updated following the identification of more diseases and the completion of additional field verifications.

Diversity and Disease Damage Methodology

Introduction

Diseases and pests are the major factors contributing to loss of harvest in crops. The resulting losses are, to a significant extent, the consequences of crops grown in monocultures and continuing evolution of new races of pests and pathogens that are able to overcome resistance genes introduced by modern breeding. Local crop genetic diversity, and the associated indigenous knowledge is a tool for small-scale farmers in developing countries to meet their livelihood needs. The use of a diversity of traditional crop varieties continues to be part of disease management strategy in genetically diverse systems for such farmers (Jarvis et al., 2011). Loss of local crops, which reduces the varietal choice, also reduces the farmers' capacity to cope with changes in pest and disease infestations, and leads to yield instability.

Mulumba et al. (2012) have shown that increased diversity of crop varieties in the case of beans (*Phaseolus vulgaris*) and banana (*Musa* spp.), as measured by number of varieties (richness) and their evenness of distribution, corresponds to a decrease in the average damage levels and reduces variance of disease damage. In sites with greater disease incidence, households with more varietal diversity in their production systems had less damage to their standing crop in the field compared to sites with less varietal diversity. Thus, increasing variety (intra-specific) diversity can be used as a risk-minimizing strategy to reduce pest and disease damage, but only if the diversity exists in relevant traits (Mulumba et al., 2012; Jarvis et al., 2016). Consequently, utilization of diversity should also be reflected in Diversity Field Schools (DFS).

Farmers in Nepal are known to grow a great richness of rice varieties even at the household level, which is often attributed to different micro-environments of their fragmented land parcels, cultural importance of certain rice varieties and the social prestige

of growing rice. However, the potential contribution of household varietal richness and evenness in reducing disease damage has not been systematically studied. Likewise, in certain high mountain districts, such as Jumla and Humla, farmers commonly cultivate several varieties of beans in a mixture, yet the potential of such traditional practices in reducing disease damage risk have not been studied. Finally, finger millet, which is a major staple crop in the mid-hills and high mountains, has remained largely neglected from a research perspective. Farmers and researchers often do not report disease incidence or damage on neglected and underutilized species (NUS) such as finger millet. Proponents of NUS have often argued that in general NUS tend to be better adapted to marginal growing conditions, genetically diverse and hence also less susceptible to disease damage. However, it could also be possible that since these crops have not been seen from a commercial perspective by farmers and extension services, the disease problems in them are ignored. By including finger millet in this study, we will also be able to see if disease incidence and severity in this NUS is indeed less than in rice and beans. In this study, we will try to see if the findings of Mulumba et al., (2012) can be replicated in the context of Nepal with rice, beans and finger millet.

Research questions

1. What is the situation of varietal richness and evenness of particular mandate crops in our community?
2. How severe are the major diseases and their incidence in rice, beans and finger millet?
3. Does the use of intraspecific diversity contribute to reduction in disease damage in the mandate crops?
4. Does disease incidence vary with intra-specific variation in crop varieties?

Hypothesis

Null hypothesis: Increasing varietal diversity does not have an effect on disease and pest severity and incidence.

Alternate hypothesis:

1. Increasing varietal diversity leads to a reduction in disease and pest severity and incidence, i.e., the Weighted Household Damage Index (WHDI) is inversely related to varietal richness at the household level.
2. WHDI is inversely related to the number of land parcels.
3. WHDI is inversely related to the spread of land parcels, i.e., WHDI is less for households that have land parcels spread far and wide from each other.
4. WHDI is inversely related to the range of elevation (i.e., vertical spread) between land parcels.
5. WHDI (mixtures) is lower than WHDI (non-mixtures).

Methodology for on-farm disease scoring

Crops

The on-farm disease diagnosis will focus on three major crops in the high altitude area: finger millet (Humla and Dolakha), rice (Lamjung) and beans (Jumla) with one of their important diseases (Table 1). These crops are selected based on their dominance in the region, high varietal diversity and economic importance of disease.

Table 1. Study sites, crops and diseases

Site	Crop choice	Major disease
Dolakha	Finger millet	Blast
Humla	Finger millet	Blast
Jumla	Common bean	Rust
Lamjung	Rice	Blast

Diseases

On-farm disease scoring will be carried out for the following diseases on selected crops: finger blast and neck blast in finger millet; panicle blast in rice; and rust in beans (Table 1). These diseases are considered as they have significant contribution in yield loss.

Research method – Household survey

The research will be carried out through survey (see Appendix 5 for household survey questionnaire) in 60 households (30 male respondents and 30 female farmer respondents– regardless of head of household). The information necessary to test the hypothesis will need to be collected over at least 3 visits. The first visit is to be made to farmer's home, second visit to standing crops and third visit after the harvest of the crops. The detail of directions and objectives for three visits are explained in the field visit below, which is supplemental to detailed methodology described by Jarvis et al. pages 32-37 in the Damage, Diversity and Genetic Vulnerability proceedings (Jarvis et al., 2011).

The first part of the household survey will cover basic information such as the households' land parcels on which they are growing the study crop, number and name of varieties of the crop grown by individual farmer, area grown, reasons for growing particular variety, farm mapping showing spatial distribution of varieties among and within plots, etc. The second part of the survey will cover field disease and pest evaluation during the second visit. For each variety grown, the farmer will give a score for each target disease or pest. The score for each variety will be the average of 30 observations (from 10 spots) and each score should be for one or more individual plants. The third part of the survey will be at farmer's place after harvest of the crop for information on use of fertilizer and pesticide inputs.

Plot/parcel sampling

Household ownership of land in mountain terraces is very scattered in the project sites and the household might have one to

several varieties in one terrace. Therefore, it is important to know how to determine 'what is the plot for a given variety or a mixture when taking field observations'? One of the exercises should be to ask the participants, especially, Technical Assistants to draw the land parcels of 2-3 different farmers along with what varieties and how they are grown in those parcels. Then ask them to show how the plots will be assigned in these diverse cases.

Figure 1 shows the illustration diagrammatically in order to understand the definition of plots and mixtures in the field condition prior to first field visit. This is important when interviewer ask farmer to draw a farm map showing boundaries, area of land for each variety. Please refer to page 32 of the Jarvis et al. (2011) book.

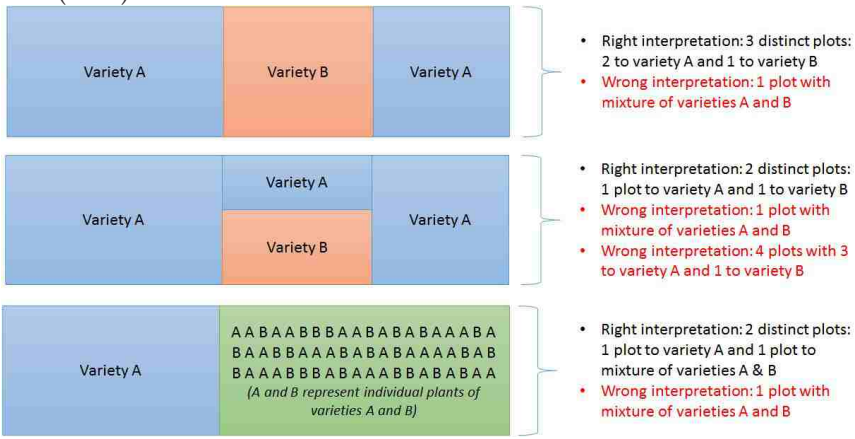


Figure 1. Diagrammatic representation of plots and mixtures in the field condition at the household level prior to first field visit. Scoring for plots where mixture of varieties are cultivated will be similar to scoring of plot where a single variety is cultivated. For example, if we are looking at X number plants in one observation (spot 1, front) to score its disease incidence and severity, then same will be done in plots with mixtures.

Field Visit

Visit 1: The purpose of the first visit is to collect information on the total area given to the crop, the varieties grown in the household, the plots the varieties are grown in and the areas of the plots. Information can be collected from the farmer at any place and not just their home but, enumerators might find it less

distracting to conduct the first survey in their homes. However, the survey should be after the farmers have planted the crop we are surveying.

Visit 2: The purpose of this visit is to record disease damage using a Z-shaped (Diagram-1) or Diagram-2 (relevant in terrace landscape of Nepal). This happens in standing crop time during the time of interest for the particular disease we are looking at. Thirty observations are made per variety in each household.* At each stopping spot make three observations: one to the left, one to the right, and one straight-ahead of about 10 plants. Rate for disease incidence in 1 to 4 scale as described below. Please note growth stage of the crop and record GPS coordinates and altitude (masl) using smart phone or GPS instrument. Although not needed specifically for this protocol, if farmers are at their plots or if we have Diversity Field School (DFS) participant farmers, this can be used as a mechanism to increase understanding of disease scoring and diversity concepts and develop local DFS resource person.

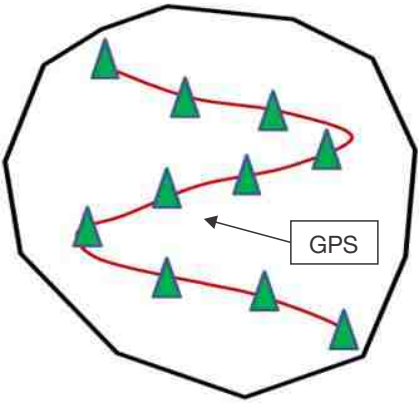


Diagram 1

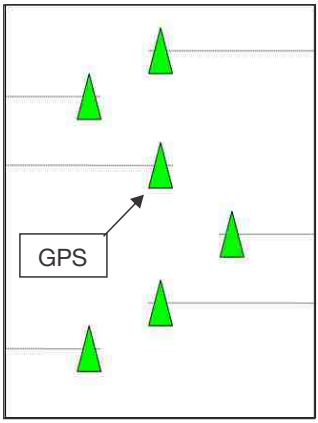


Diagram 2

* In certain cases, a variety might be grown in a very small plot (6m3 or less) either because it is grown for ritualistic use (e.g., Anadi) or it is a new variety the farmer is testing out. In these cases, observations even from 2 spots (i.e., 6 observations) may be adequate to give a full picture of the disease condition for this variety. In such cases, 30 observations of disease incidence and disease severity will not be necessary.

Visit 3: This will happen after the harvest time, where the enumerator will go to the farmers to collect information on the pesticides used that season. Since we are visiting the farmer at the end of the season, we can also collect perceived yield data. If we plan our cards right, we can also give them the disease scoring of their fields after we collect the yield and the pesticide data.

Disease scoring methods

We present adaptation of **disease severity** scoring to 1-4 scale from presently available 1-9 scale of international methods for specific disease and field guide for disease identification (following chapters) and scoring methods in mandate crops by Manandhar et al. (2016, This book). In fact, the above-mentioned scoring scales have been developed for on-station screening of crop genotypes and breeding lines for disease resistance and for in-depth study of host resistance to specific diseases. Since one of the main objectives of this guide is to facilitate on-farm evaluation of crop genotypes by field staff and even by farmers (other than trained plant pathologists in most cases) a need of simplified disease scoring scales was felt. For this purpose, an exercise was made separately by a team to consolidate the described scales into four groups: resistant (scale 1), moderately resistant (scale 2), moderately susceptible (scale 3) and susceptible (scale 4). This will be used to measure on-farm disease damage assessment for household survey.

The purpose of on-farm disease scoring is to obtain objective observations of the severity and incidence of diseases and pests for each variety the farmer is growing by collecting the observations in such a way that they are representative of each farm. For each variety the farmer grows give a score for each project target disease or pest. The score for each variety will be the average of 30 observations and each score should be for one or more individual plants. Adapted methods for estimating disease incidence and severity for selected diseases of target crops are explained below.

Disease incidence and **disease severity** should be recorded in each observation separately at each spot. **Disease Incidence** refers to proportion or percentage of diseased plants (entities) within a sample population and should be recorded first. **Disease Severity** refers to severity in the quantity of disease affecting plants (entities) within a sample population (Seem, 1984; Schoonoven and Pastor-Corrales, 1994). It is highly recommend as an exercise on recording disease incidence and severity for rice, bean and finger millet plots that mixtures of 2 or 3 varieties are grown. The field staff need to be clear on how to record the data and do calculations on these cases as well (see example at the end).

Finger Millet

Disease: Blast *Pyricularia grisea (Magnaporthe grisea)*

Field disease scoring guide for neck and finger blast of finger millet (record at physiological seed maturity growth stage) as follows:

1. Disease Incidence

Neck blast

$$\text{Percent of disease incidence (\%)} = \frac{\text{Number of infected neck}}{\text{Total numbers of ear heads observed}} \times 100$$

Finger blast

$$\text{Percent of disease incidence (\%)} = \frac{\text{Number of infected finger}}{\text{Total numbers of ear heads observed} \times \text{Number of finger per head}} \times 100$$

Percentage of disease incidence	Host Response
0 - 10 %	Resistant
11 – 30 %	Moderately resistant
31 – 60 %	Moderately susceptible
61 - 100 %	Susceptible

(Scale modified from Hill Crop Research Programme, Kabre, NARC)

Disease incidence will be recorded by the field staff in percentages in the multiples of 10 (whichever is easier) from 0 to 100%.

2. Disease Severity

Estimate disease severity by observing sizes of lesion and its extent (spread) in the diseased plant parts.

Neck blast

Scale	Reaction	Host Response
1	No lesions to pin head size of lesions on the neck region.	Resistant
2	0.1 to 2.0 cm size of typical blast lesion on the neck region.	Moderately resistant
3	2.1 to 4.0 cm size of typical blast lesion on the neck region.	Moderately susceptible
4	> 4.0 cm size of typical blast lesion on the neck region. Corresponds to 4 to 5 rating on the Kiran Babu et al. (2013) scale.	Susceptible

(Scale modified from Kiran Babu et al., 2013)

Disease severity will be recorded by the field staff on the scale of 1- 4.

Finger blast

Finger blast severity estimate is recorded as visual percentage of blasted florets across all tillers of a plant (Figure below).

Scale	Reaction	Host Response
1	No or pin head size lesion on neck. Corresponds to 0.1-2 cm on the Kiran Babu et al. (2013) scale.	Resistant
2	Fully girdled neck with lesions and head with few fingers infected. Corresponds to 2.1 to 3 cm on the Kiran Babu et al. (2013) scale.	Moderately resistant
3	2.1 to 4.0 cm lesions on neck region with 50% of fingers of head infected. Corresponds to 3.1 to 4 cm on the Kiran Babu et al. (2013) scale.	Susceptible
4	>4.0 cm lesions with > 50% of fingers of head infected. Corresponds to 4.1 to 5 cm on the Kiran Babu et al. (2013) scale.	Highly susceptible

(Scale modified from Kiran Babu et al., 2013)

1 2 3 4 5

(Source: Kiran Babu et al., 2013)

Bean

Disease: Rust *(Uromyces appendiculatus)*

Field Disease Scoring Guide of rust for common beans (record at 50% pod filling R8 growth stage).

1. Disease Incidence

Eye estimate numbers or proportion of diseased plants within a sample population. Disease incidence will be recorded by the field staff in percentages in the multiples of 5 from 0 to 100%.

2. Disease Severity

Estimate the extent of pustules in the leaflet area of the sample population.

Scale	Reaction	Host Response
1	No or few pustules with yellow halo. No symptom or 1-10% leaflet area with lesions. Corresponds to 0-1 scale on the scale of Inglis et al., 1988.	Resistant
2	Few scattered pustules common on leaves and easily observed but causing no apparent damage; 11-25% leaflet area with lesions. Corresponds to 2 on the scale of Inglis et al., 1988.	Moderately resistant
3	Pustules very common and damaging, few pustules on petioles, stems and pods; 26-50% leaflet area with lesions and limited chlorosis. Corresponds to 3 on the scale of Inglis et al., 1988.	Moderately susceptible
4	Pustules very extensive on all plant parts, some death of leaves and other plant parts; over 50% lesions and extensive chlorosis (yellowing), and complete defoliation. Corresponds to 4-5 on the scale of Inglis et al., 1988.	Susceptible

(Modified from ICARDA guideline and recalibrated with Inglis et al., 1988)

Rice

Disease: Panicle Blast *Pyricularia oryzae (Magnaporthe oryzae)*

Field Disease Scoring Guide of panicle blast for rice (record at growth stage 8-9, dough to maturity).

1. Disease Incidence

Disease incidence was considered to be percentage of panicles showing any level of panicle blast:

$$\text{Percent of disease incidence (\%)} = \frac{\text{Number of infected panicle}}{\text{Total numbers of panicle observed}} \times 100$$

2. Disease Severity

Visual examination of percentage of branches that shows necrosis due to infection.

Scale	Reaction	Host Response
1	0 – 5% of panicles with lesions covering completely around the node. Corresponds to 1-3 on the IRRI scale.	Resistant
2	6 – 25% of panicles with lesions covering completely around the node. Corresponds to 4-5 on the IRRI scale.	Moderately resistant
3	26 – 50% of panicles with lesions covering completely around the node. Corresponds to 6-7 on the IRRI scale.	Moderately susceptible
4	>50% of panicles with lesions covering completely around the node. Corresponds to 8-9 on the IRRI scale.	Susceptible

(Modified from IRRI, 2002; Zhu et al., 2004)

Field Observation Sheet

Variety name:

HH number:

Obs.	Spot	Disease 1/ Rust		DI calculation (Incidence x Severity) / highest severity	DI (Damage Index)	GPS reading (1 at the centre of the plot; see diagram 1 & 2)
		Incidence (%)	Severity (1-4)			
01	Spot 1-right					
02	Spot 1-left					
03	Spot 1-in front					
04	Spot 2-right					
05	Spot 2-left					
06	Spot 2-in front					
...	...					
...	...					
...	...					

Obs.	Spot	Disease 1/ Rust		DI calculation (Incidence x Severity) / highest severity	DI (Damage Index)	GPS reading (1 at the centre of the plot; see diagram 1 & 2)
		Incidence (%)	Severity (1-4)			
028	Spot 10-right					
029	Spot 10-left					
030	Spot 10-in front					

* Obs. = Observations

Calculating disease damage indices

EXAMPLE: Ratings for Disease severity and incidence

Variety Name _____

EXAMPLE: Leaf Blast in Rice

Disease Severity (Scale 1-4)

Percent of Disease Incidence (0-100 %)

Obs.	Spot	Disease Incidence Scoring Crop: Rice; Variety: *Lumle-2*			
		Leaf Blast		DI calculation (Incidence X severity) / highest severity	Damage Index (DI)
		% incidence in population observed (0-100%)	Severity (1-4)		
01	Spot 1 - right	60	2	= (60*2)/4	30
02	Spot 1 - left	30	1	= (30*1)/4	7.5
03	Spot 1 - front	0	0	= (00*0)/4	0
04	Spot 2 - right	10	1	= (10*1)/4	2.5
05	Spot 2 - left	20	3	= (20*3)/4	15
06	Spot 2 - front	20	3	= (20*3)/4	15
				Mean (Lumle-2)	11.7

* Obs. = Observations

Example of WDI (Weighted Damage Index) Calculation

Variety	Proportion of Area	DI	WDI
Lumle -2	0.3	11.7	0.3*11.7 = 3.51
Chhomrong	0.7	50.2	0.7*50.2 = 35.14
			3.51 + 35.14 = 38.65

References

Jarvis, D.I., Fadda, C., De Santis, P. and Thompson, J. eds. 2011. Damage, diversity and genetic vulnerability: The role of crop genetic diversity in the agricultural production system to reduce pest and disease damage, Proceedings of an International Symposium 15-17 February, 2011, Rabat, Morocco. Bioversity International, Rome Italy.

ICARDA undated. ICARDA International Nurseries Guideline, ICARDA, Syria (unpublished).

Inglis, D.A., Haedorn, D.J. and Rand, R.E. 1988. Use of dry inoculum to evaluate beans for resistance to anthracnose and angular leaf spot. Plant Disease 72:771-774.

IRRI. 2002. Standard evaluation system for rice. International Rice Research Institute, Los Banos, Manila, Philippines.

Mulumba, J.W., Nankya, R., Adokorach, J., Kiwuka, C., Fadda, C., De Santis, P. and Jarvis, D.I., 2012. A risk-minimizing argument for traditional crop varietal diversity use to reduce pest and disease damage in agricultural ecosystems of Uganda. Agriculture, Ecosystems and Environment 157 (2012): 70-86.

CIAT (Centro Internacional de Agricultura Tropical). 1987. Standard System for the Evaluation of Bean Germplasm. van Schoonhoven, A., and Pastor-Corrales, M.A. (compilers). The International Center for Tropical Agriculture, Cali, Colombia.

Kiran Babu, T., Thakur, R.P., Upadhyaya, H.D., Reddy, P.N., Sharma, R., Girish, A.G. and Sarma, N.D.R.K. 2013. Resistance to blast (*Magnaporthe grisea*) in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology 135(2):299-311. DOI 10.1007/s10658-012-0086-2

Seem, R.C. 1984. Disease incidence and severity relationships. Annual Review of Phytopathology 22(1):133-150.

Zhu, Y.Y., Fang, H., Wang, Y.Y., Fan, J.K., Yang, S.S., Mew, T.W. and Mundt, C.C. 2004. Panicle blast and canopy moisture in rice cultivar mixtures. Phytopathology 95:433-438.

Chapter 1
Amaranth (*Amaranthus* spp. L.) Diseases

Disease

Anthracnose (एन्थ्राक्नोज / कोट्रे)

Anthracnose is a common fungal disease of amaranth plants. The fungus is seed borne and survives in infected crop debris. The disease was identified from Jumla for the first time in 2015.

Pathogen

Colletotrichum gloeosporioides

Credit: Shrinkhala Manandhar

Setae (left) and conidia (right) of *Colletotrichum gloeosporioides*

Identification

Small sunken necrotic lesions surrounded by yellow halo appears on leaves in the beginning and the lesions enlarge causing dieback of leaves and branches.

Credit: Hira Kaji Manandhar

Anthracnose symptoms on leaves of amaranth, initial spots (left)

Scoring

Scale	Plant parts affected
0	No disease.
1	1-10% leaflet area with lesions.
2	11-25% leaflet area with lesions.
3	26-50% leaflet area with lesions and limited chlorosis.
4	Over 50% or more of the leaflet area with lesions and extensive necrosis.
5	Defoliation.

(Adopted from Inglis et al., 1988, described for bean diseases)

Disease

Cercospora leaf spot (सर्कोस्पोरा लिफ स्पट / सर्कोस्पोरा पाते थोप्ले)

Cercospora leaf spot is a commonly occurring fungal disease of amaranth. The fungus is seed borne and survives in infected crop debris and other host plants.

Pathogen

Cercospora canescens

Credit: Shrinkhala Manandhar

Conidiophores in bunch (left) and Conidia (right) of *Cercospora canescens*

Identification

The leaf spots are subcircular to broadly irregular, generally having a brown, pale tan to gray centre surrounded by a dark brown margin. Characteristic lesions are round, brown and necrotic with dark, slightly depressed edges. Initial symptoms appear as brown small necrotic patches.

Credit: Hira Kaji Manandhar

Cercospora spots with yellowing of amaranth leaves; initial spots (left)

Scoring

Scale	Leaf area affected
1	No or initial spots.
3	Spots scattered.
5	Spots common on leaves and easily observed but causing no apparent damage.
7	About 70% leaf area covered with spots.
9	90% leaf area damaged.

(Adopted from ICARDA International Nursery Guidelines described for small grain legumes)

Disease

Rhizoctonia blight (राइजोक्टोनिया व्लाइट / राइजोक्टोनिया डढुवा)

Rhizoctonia blight is a fungal disease. Under warm and humid conditions the disease may cause significant damage to the crop. The disease was found in Pokhara area for the first time in 2015.

Pathogen

Rhizoctonia solani

Credit: Suk Bahadur Gurung

Hyphae of *Rhizoctonia solani*

Identification

Symptoms appear on leaves as white irregularly shaped spots causing blight. The blighted portion drops off causing holes on the leaves.

Credit: Suk Bahadur Gurung

Blighted leaves, close up (right)

Scoring

Scale	Plant parts affected
0	No disease.
1	1-10% leaflet area with lesions.
2	11-25% leaflet area with lesions.
3	26-50% leaflet area with lesions and limited chlorosis.
4	Over 50% or more of the leaflet area with lesions and extensive necrosis.
5	Defoliation.

(Adopted from Inglis et al., 1988, described for bean diseases)

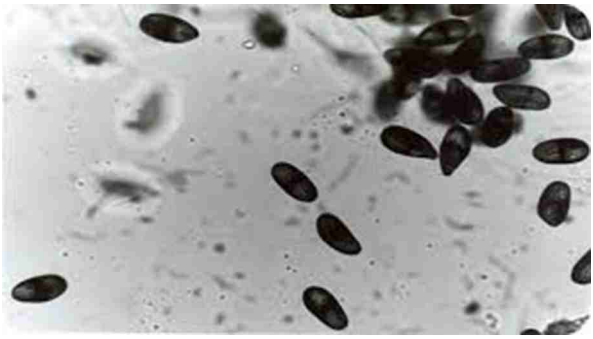
Disease

Wet rot (वेट रट् / कुहिने)

Wet rot is an important fungal disease of amaranth. In Nepal, the disease has not been observed in amaranth, but an epidemic of the disease occurred on chilli in the mid-Western terai.

Pathogen

Choanephora cucurbitarum



Source: http://escijournals.net/index.php/phytopath/article/download/234/pdf_28

Conidia of *Choanephora cucurbitarum*

Identification

Water-soaked lesions on stems; lesions have a hairy appearance due to the presence of fungal spores; may cause loss of leaves. Large bright round lesions develop on the leaves with concentrically dark rings consisting of numerous pycnidia; dead tissue often becomes brittle. The pathogen confined on apical young shoots giving blighted curved structure.

Source: Awurum and Uchegbhu, 2013

Wet rot of amaranth

Scoring

Scale	Plant parts affected
0	No disease.
1	1-10% leaflet area with lesions.
2	11-25% leaflet area with lesions.
3	26-50% leaflet area with lesions and limited chlorosis.
4	Over 50% or more of the leaflet area with lesions and extensive necrosis.
5	Defoliation.

(Adopted from Inglis et al., 1988, described for bean diseases)

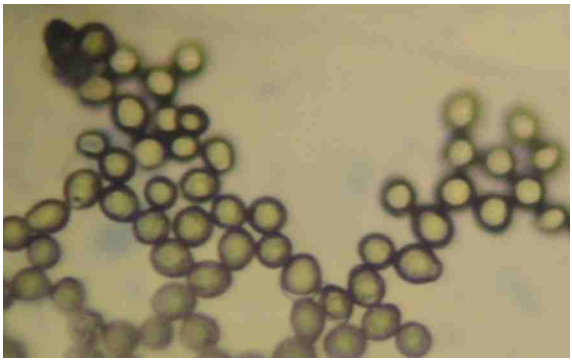
Disease

White rust (ह्वाइट् रस्ट / सेतो सिन्दुरे)

White rust is a major fungal disease during the summer season in hot and humid conditions. The disease occurs when nights are cool and damp and days are warm. The disease reduces the commercial value of the crop (leafy vegetable).

Pathogen

Albugo bliti



Credit: Suk Bahadur Gurung

Spores of *Albugo bliti*

Identification

Distinctive chalky white spore masses sometimes referred to

as pustule first appear on the undersides of leaves. These blister-like masses called sori form under the leaf dermis and cannot be scraped-off without damaging the leaf.

Credit: Sandesh Neupane

Credit: Ram Devi Timila

White rust on upper (left) and lower surface of amaranth leaves (right)

Scoring

Scale	Leaf area infected
0	No symptoms on leaves.
1	Up to 10% leaf area infection.
2	11-30% leaf area infection.
3	31-50% leaf area infection.
4	51-70% leaf area infection.
5	71% and above leaf area infection.

(Adopted from Mehta and Mondal, 1978, described for tikka disease of groundnut)

Scale	Leaf area affected
0	No symptoms.
1	Less than 5 pustules per leaf.
2	More than 5 pustules and less than 1/10th of leaf area affected.
3	More than 1/10th, but less than half of leaf area affected.
4	More than half of leaf area affected.

(Source: Wang and Elbert, 2012)

Disease

Collar rot (कोलार रट् / फेद कुहिने)

Collar rot is an important fungal disease of amaranth. The fungus is widespread and soil borne. The disease was found at Khumaltar, Lalitpur for the first time in 2012.

Pathogen

Sclerotium rolfsii

Identification

Growing or adult plants become dried or dead with whitish growth on the base of the plants and soil surface. On close-up view, ramified mycelial growth around the collar region of the plant with formation of minute spherical sclerotia can be seen. At maturity, the sclerotia turn brown and resemble mustard seeds.

Credit: Hira Kaji Manandhar

Collar rot symptom of same amaranth plant at different close up

Scoring

Count the number of dead plants and calculate the percentage.

$$\text{Percent of disease incidence (\%)} = \frac{\text{Number of dead plants}}{\text{Total number of plants}} \times 100$$

References

Awurum, A.N. and Uchegbu, P.C. 2013. Development of wet rot disease of *Amaranthus cruentus* L. caused by *Choanephora cucurbitarum* (Berk. and Rav.) Thax. in response to phytochemical treatments and inoculation methods. Advancement in Medicinal Plant Research 1(3):66-71.

Inglis, D.A., Haedorn, D.J. and Rand, R.E. 1988. Use of dry inoculum to evaluate beans for resistance to *anthracnose* and angular leaf spot. Plant Disease 72:771-774.

Mehta, P.P. and Mondal, K.K. 1978. Field screening of groundnut cultivars against rust of tikka. Indian Phytopathology 31:259-260.

Sealy, R.L., Kenerley, C.M. and McWilliams, E.L. 1988. Evaluation of Amaranthus accessions for resistance to damping-off by *Pythium myriotylum*. Plant Disease 72:985-989.

Talukder, M.M.R., Riazuddin, M., Rahman, M.M., Uddin, M.S. and Khan, M.S.I. 2013. Efficacy of fungicides to control white rust (*Albugo occidentalis*) of red amaranth (*Amaranthus* sp.). Bangladesh Journal of Plant Pathology 28(1&2):15-17.

Teri, J.M. and Mlasani. 1994. Choanephora blight and Alternaria leaf spot of Amaranth in Tanzania. Plant Pathology 43(1):228-229.

Wang, S.T. and Ebert, A.W. 2012. Breeding of leafy amaranth for adaptation to climate change. Conference: Regional Symposium on High Value Vegetables in Southeast Asia: Production, Supply and Demand (SEAVEG2012), At Chiang Mai, Thailand, Volume: AVRDC – The World Vegetable Center, Publication No. 12-758.

https://www.plantvillage.org/en/topics/amaranth/infos/diseases_and_pests_description_uses_propagation.

UK. 2011. Grain Amaranth. University of Kentucky. Available at: https://www.uky.edu/Ag/CCD/introsheets/amaranth.pdf.

Chapter 2
Barley *(Hordeum vulgare* L.*)* Diseases

Disease

Stripe rust (स्ट्राइप रस्ट / धर्से सिन्दुरे, पहेंलो सिन्दुरे)

Stripe rust, also known as yellow rust, is the most destructive fungal disease of barley in the hills of Nepal, occurring at an altitude of 1000-2500 m in cooler and high altitudes. The rust is wind borne and favoured by low temperature of 10-15ºC with dew and frequent air flow.

Pathogen

Puccinia striiformis* f. sp. *hordei

Credit: Shrinkhala Manandhar

Uredospores of *Puccinia striiformis* f. sp. *hordei*

Identification

Symptoms in seedlings are different from adult plants. In seedlings, small yellow elongated pustules containing thousands of uredospores are uniformly distributed over the entire leaf surfaces. In mature plants, the pustules are arranged in linear stripes (parallel) on leaf blades and leaf sheaths. In severe cases, the pustules are also seen on awns and inside and outside of the glumes. As plants near maturity and unfavourable environmental conditions develop, the pustules turn black and are covered by teliospores.

Stripe rust; on whole barley plant (left), initial (middle left), developed (middle right) and covering whole leaf area showing highly susceptible reaction (right)

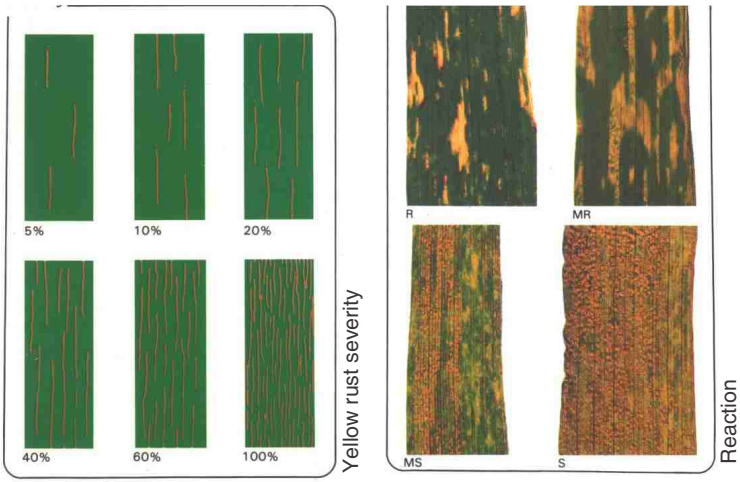
Scoring

Rust development is correlated with host development and growth stage. The best time for rust scoring is when the susceptible cultivar expresses a fully susceptible reaction and incidence. Scoring should thus be done between the growth stage 10.5 and 11.1 (all spikes out of sheath and milky ripe, respectively). Growth stage should be noted as it is related to yield loss.

Rust scoring is based on severity (percentage of rust infection on the leaves) and disease reaction (resistant, intermediate or susceptible). Rust severity is recorded as a percentage, according to the modified Cobb scale, based on visual observations (see picture).

Disease reaction is recorded as no infection (0), resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S) (see picture) where,

0	No visible infection on plants
R	Resistant; visible chlorosis or necrosis, no uredia present.
MR	Moderately resistant; small uredia present and surrounded by either chlorotic or necrotic areas.
MS	Moderately susceptible; medium size uredia present and possibly surrounded by chlorotic areas
S	Susceptible; large uredia present, generally with little or no chlorosis and no necrosis.



Rust Scoring Guide (IPO and CIMMYT)

Reading of severity and reaction are recorded together with severity first. For example,

TR	Trace severity with a resistant type reaction
5 MR	5% severity with a moderately resistant type infection
60 S	60% severity with a susceptible type infection

Disease

Stem rust (स्टेम रस्ट / कालो सिन्दुरे, डाँठे सिन्दुरे)

Stem rust, also known as black rust, is a fungal disease of minor importance in Nepal. The disease occurs near crop maturity.

Pathogen

Puccinia graminis

Identification

Pustules are brick red to brown, oval to elongated, usually surrounded by torn margins. The pustules appear on stem sheaths and awns. At first, pustules are scattered but later they coalesce to form big pustules. In severe cases, pustules also occur on the awns and in mature plants, pustules turn into black spores.

Source:http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/rusts-of-barley

Stem rust on barley

Scoring

Rust development is correlated with host development and growth stage. The best time for rust scoring is when the susceptible cultivar expresses a fully susceptible reaction and incidence. Scoring should thus be done between the stage 10.5 and 11.1 (all spikes out of sheath and milky ripe, respectively). Growth stage should be noted as it is related to yield loss.

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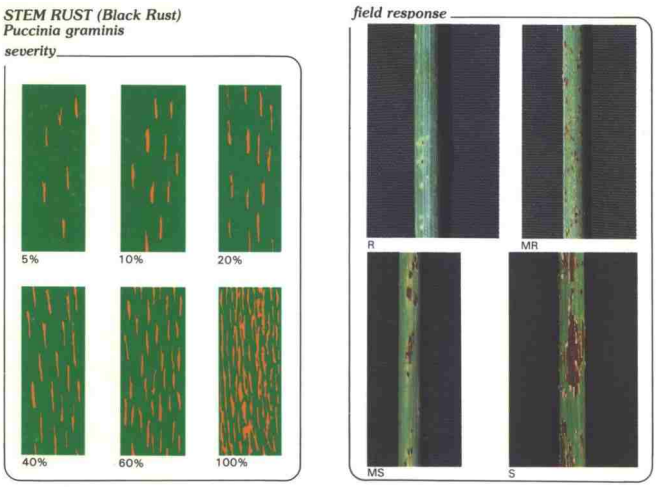

Rust Scoring Guide (IPO and CIMMYT)

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5 MR	5% severity with a moderately resistant type infection
60 S	60% severity with a susceptible type infection

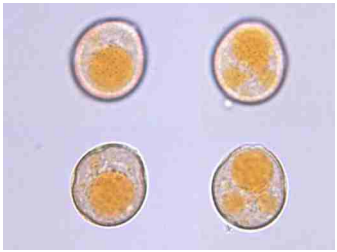
Disease

Leaf rust (लिफ् रस्ट / पाते सिन्दुरे, खैरो सिन्दुरे)

Leaf rust, also known as brown rust, is a minor fungal disease of barley in the hills of Nepal. Yield losses result primarily from a reduction in kernel number and shriveling of grains.

Pathogen

Puccinia hordei



Source: www.pflanzenkrankheiten.ch/de/krankheiten-an-kulturpflanzen/getreide-mais/gerste/268-puccinia-hordei

Uredospores of *Puccinia hordei*

Identification

Orange-coloured pustules appear on leaves and stems, leaf sheaths and ears. Pustules develop yellow halo on leaves. Small black pustules also develop on the underside of the leaf.

Source: http://tolweb.org/Pucciniomycetes/51246)

Leaf rust on barley

Scoring

Rust development is correlated with host development and growth stage. The best time for rust scoring is when the susceptible cultivar expresses a fully susceptible reaction and incidence. Scoring should thus be done between the stage 10.5 and 11.1 (all spikes out of sheath and milky ripe, respectively). Growth stage should be noted as it is related to yield loss.

Rust scoring is based on severity (percentage of rust infection on the leaves) and disease reaction (resistant, intermediate or susceptible). Rust severity is recorded as a percentage, according to the modified Cobb scale, based on visual observations (see picture).

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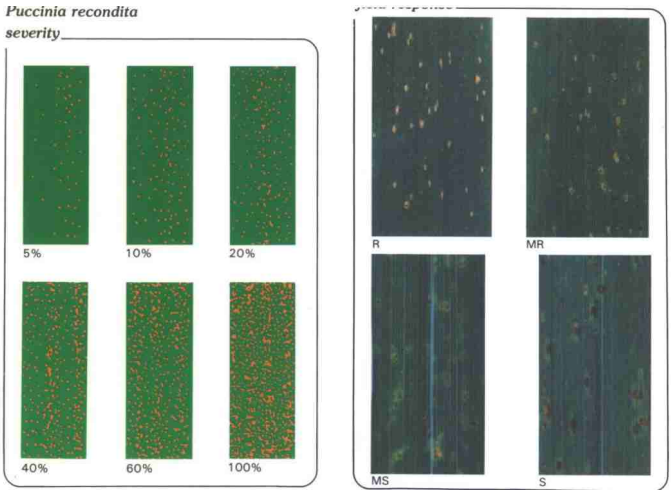

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Reading of severity and reaction are recorded together with severity first. For example,

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5 MR	5% severity with a moderately resistant type infection
60 S	60% severity with a susceptible type infection

Disease

Barley stripe (बार्ली स्ट्राइप / धर्से)

It is the second most important fungal disease of barley in Nepal. It is a systemic and seed borne disease. The fungus becomes active during seed germination invading coleoptiles and infecting each of the leaves as they develop. In some infected fields there is very little grain formation. The disease is restricted mainly on cooler areas of hills and is quite devastating in some pockets. As much as 90 percent yield reduction was recorded at Khumaltar on a local barley variety.

Pathogen

***Helminthosporium gramineum* (Teleomorph*: Pyrenophora graminea*)**

Credit: F.J. Zillinsky (Zillinsky, 1983)

Conidia of *Helminthosporium gramineum*

Identification

Initial symptom appears as yellow or pale stripe parallel to the vein on leaf blades. These stripes gradually enlarge as the leaf becomes larger and changes in colour to brown. Later, stripes split lengthwise (along the stripe). In severe cases, plants become stunted and do not form heads. Even if the heads are formed, kernels are not formed or are shriveled.

Source: www.agric.wa.gov.au/mycrop/diagnosing-barley-stripe

Barley stripe

Scoring

Scoring is done by counting diseased and healthy plant.

Scale	Plant infected
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

Disease

Powdery mildew (पाउडरी मिल्ड्यू / धुले ढुसी)

Powdery mildew is a major fungal disease of barley occurring mostly in cool, shady and moist places. High incidence of the disease has been recorded in the high hill areas like Jumla, Kabre, Lumle, and Pakhribas.

Pathogen

Blumeria graminis* f. sp. *hordei* (syn. *Erysiphe graminis* f. sp. *hordei)

Credit: Shrinkhala Manandhar

Conidia of *Blumeria graminis* f. sp. *hordei*

Identification

Symptoms appear first on the upper surface of lower leaves as round or oval spots or blisters on which a white or yellow mass of mycelium is observed. Infected tissues first look yellow, then

turn brown and die. Spots also appear on leaf sheaths, glumes, as well as awns and become powdery in appearance. Dark spherical bodies (cleistothecia) may develop in the cottony mycelia on older leaves.

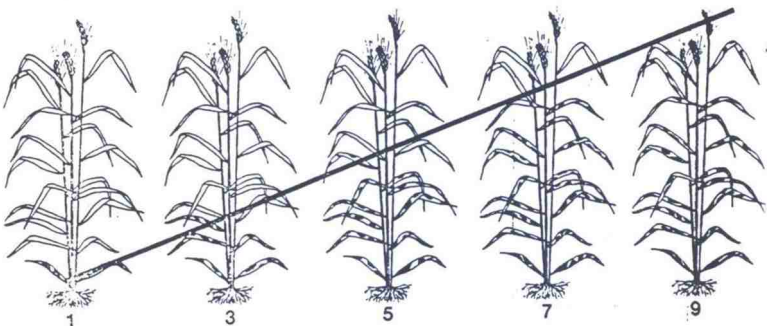
Credit: Hira Kaji Manandhar

Source: www.blog.apotekaras.rs/pepelnica-zita-blumeria-graminis-erysiphe-graminis

Powdery mildew on barley leaf (left); on spike and leaf (right)

Scoring

For recording infection of powdery mildew and other foliar diseases like spot blotch, net blotch and scald, scoring is applied to whole plant and hinges on the value of 5 which has been defined as the midpoint (see below the descriptions and pictorial diagram).

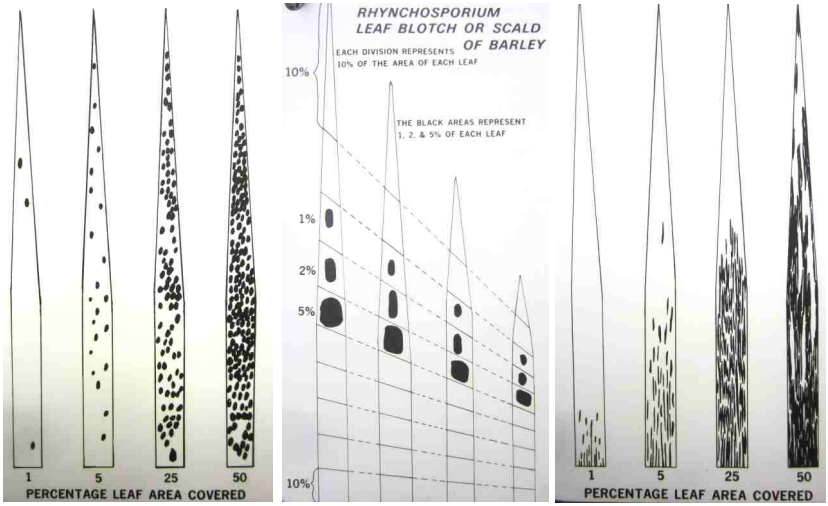


Scale for appraising the intensity of foliar diseases in wheat and barley (Saari and Prescott, 1975)

Key to Figure: Description of severity levels (Saari and Prescot, 1975)

0	Free from infection.
0E	Free from infection, but probably represents an escape.
1	Resistant: A few isolated lesions on only the lowest leaves.
2	Resistant: Scattered lesions on the second set of leaves with first leaves lightly infected.
3	Resistant: Light infection of lower third of plant; lowermost leaves infected at moderate to severe levels.
4	Moderately resistant: Moderate infection of lower leaves with scattered to light infection extending to the leaf immediately below the middle of the plant.
5	Moderately susceptible: Severe infection of lower leaves; moderate to light infection extending only to the middle of the plant.
6	Moderately susceptible: Severe infection on lower third of plant, moderate on middle leaves and scattered lesions beyond the middle of the plant.
7	Susceptible: Lesions severe on lower and middle leaves with infection extending to the leaf below the flag leaf, or with trace infection on the flag leaf.
8	Susceptible: Lesions severe on lower and middle leaves; moderate to severe infection of upper third of plant; flag leaf infected in amounts more than a trace.
9	Highly susceptible: Severe infection on all leaves; spikes also infected to some degree.

More advanced scoring is a double digit system (both the height and severity). Please refer to appendix 4 for double digit system. If disease has reached 7 by height and 6 by severity then the total score is 76. The pictorial guide for estimating disease severity by James (1971) is given below.



Powdery mildew | Scald | Blotch or stripe

Based on the pictorial guide by James (1971), the following scale is suggested for measuring disease severity.

Scale	Leaf area covered by disease
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

Disease

Spot blotch (स्पट व्लच / थोप्ले धब्बे)

Spot blotch is a fungal disease, mostly found under warm wet conditions. The fungus is seed borne, survives in infected stubble and is capable of surviving as a saprophyte on dead tissues. Seedling infection causes blight, which frequently results in pre- or post-emergence seedling death.

Pathogen

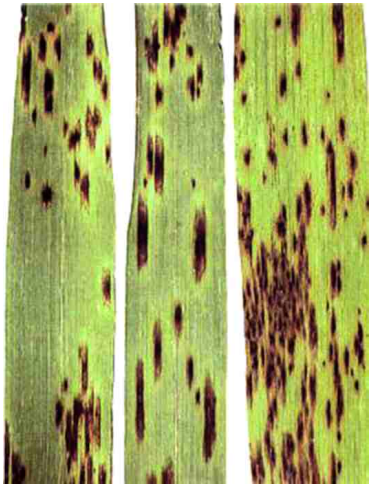
***Bipolaris sorokiniana* (syn. *Helminthosporium sativum*)**

Photo: F.J. Zillinsky (Zillinsky, 1983)

Conidia of *Bipolaris sorokiniana*

Identification

Small pinpoint to 1-2 mm-sized spots develop on leaves and leaf sheaths, and become round to oblong brown lesions with yellow halos. Later, the spots enlarge and coalesce to form large lesions that cover a major portion of the leaf giving the leaf a blighted appearance.

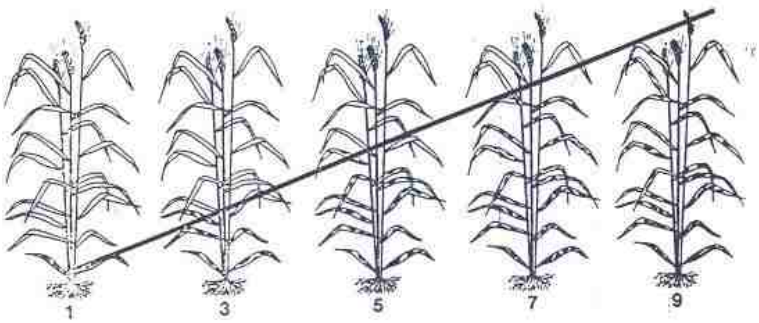


Source: www.agroatlas.ru/en/content/diseases/Hordei/Hordei_Bipolaris_sorokiniana/

Spot blotch on barley leaves

Scoring

For recording infection of spot blotch and other foliar diseases like powdery mildew, net blotch and scald, scoring is applied to whole plant and hinges on the value of 5 which has been defined as the midpoint (see below the descriptions and pictorial diagram).



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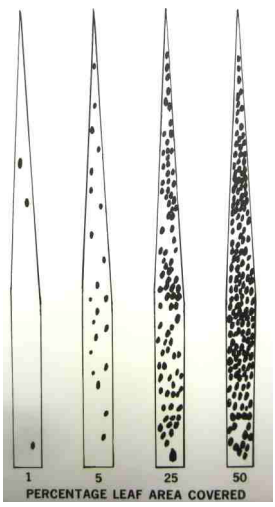
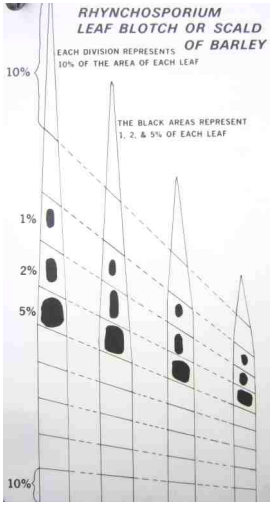


Powdery mildew



Scald

Blotch or stripe

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Scale	Leaf area covered by disease
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

Disease

Net blotch (नेट ब्लच / जाली धब्बे)

Net blotch is one of the most important fungal diseases of barley in Nepal, especially in the hills having wetter conditions with stubble retained. It develops from infected seed and conidia that develop on infested straw and stubble.

Pathogen

Helminthosporium teres (*Teleomorph: *Pyrenophora teres)

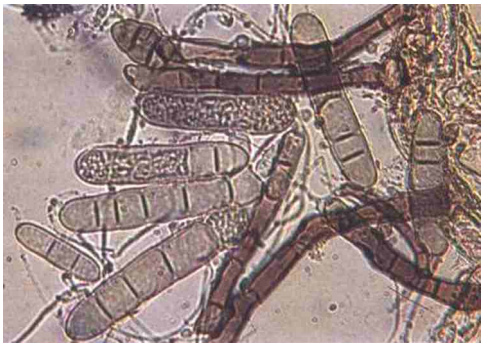


Photo: F.J. Zillinsky (Zillinsky, 1983)

Conidia of *Helminthosporium teres*

Identification

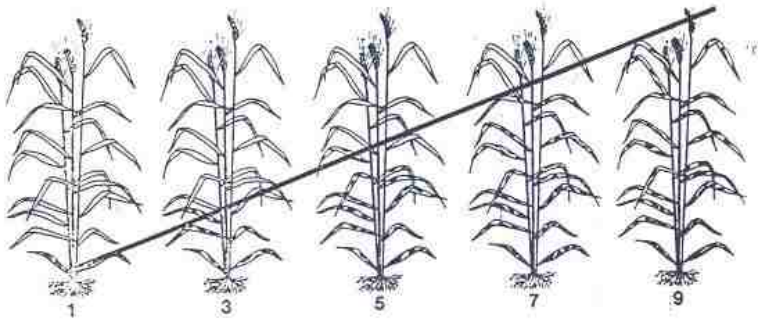
Distinct net-like symptoms are seen on the young leaves of susceptible varieties. Severely infected leaves may become completely necrotic and dry up. In the adult stage, elongated lesions appear on leaf blades, leaf sheaths, and glumes.

Source: www.agroatlas.ru/en/content/diseases/Hordei/Hordei_Pyrenophora_teres

Net blotch of barley

Scoring

For recording infection of net blotch and other foliar diseases like spot blotch, powdery mildew and scald, scoring is applied to whole plant and hinges on the value of 5 which has been defined as the midpoint (see below the descriptions and pictorial diagram).



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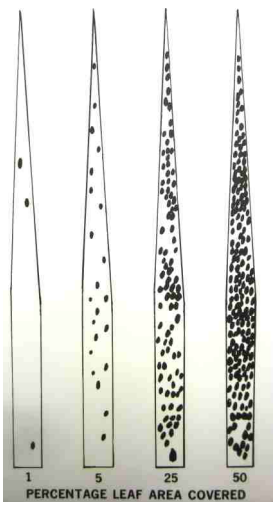
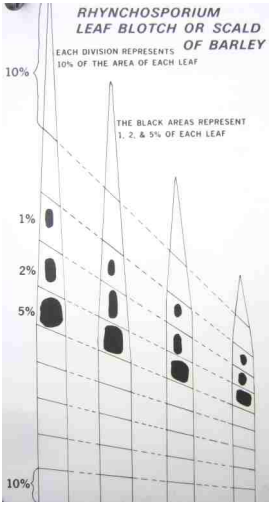
8	Susceptible: Lesions severe on lower and middle leaves; moderate to severe infection of upper third of plant; flag leaf infected in amounts more than a trace.
9	Highly susceptible: Severe infection on all leaves; spikes also infected to some degree.

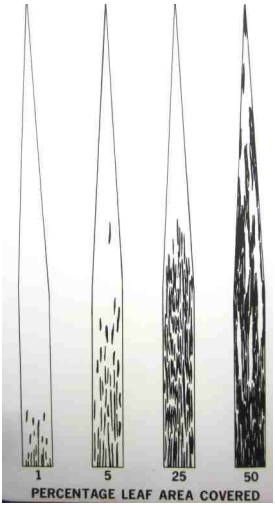
More advanced scoring is a double digit system (both the height and severity). Please refer to appendix 5 for details. If disease has reached 7 by height and 6 by severity then the total score is 76. The pictorial guide for estimating disease severity by James (1971) is given below.



Powdery mildew



Scald



Blotch or stripe

Based on the pictorial guide by James (1971), the following scale is suggested for measuring disease severity.

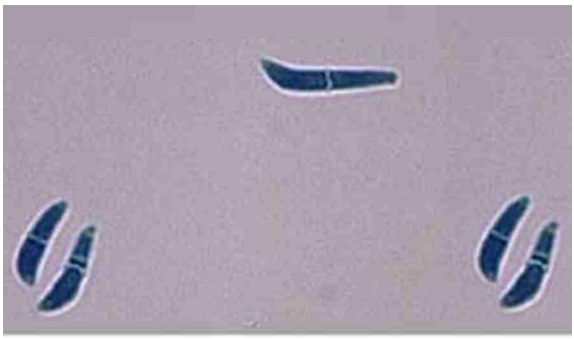
Scale	Leaf area covered by disease
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

Disease

Scald (स्काल्ड / डढुवा)

Scald is a common fungal disease in the temperate region. It is a minor disease but can cause significant yield losses in cool, wet seasons. The fungus is seed borne and survives in infected host residue as the principle source of primary inoculum.

Pathogen
Rhynchosporium secalis



Source: www.pflanzenkrankheiten.ch/de

Conidia of *Rhynchosporium secalis*

Identification

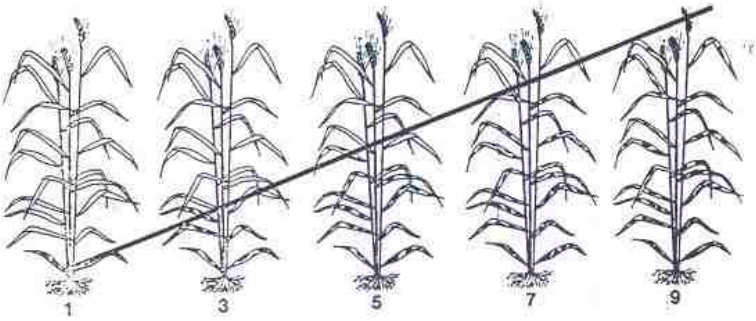
Distinct dark, pale or bluish lesions are seen on the leaf blade. Later, the center of the lesion becomes tan or white.

Source: www.bayercropsscience.co.uk

Scald on barley leaves

Scoring

For recording infection of scald and other foliar diseases like spot blotch, net blotch and powdery mildew, scoring is applied to whole plant and hinges on the value of 5 which has been defined as the midpoint (see below the descriptions and pictorial diagram).



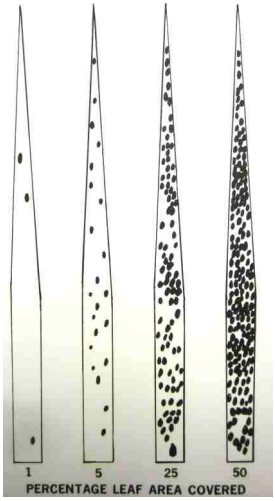
Scale for appraising the intensity of foliar diseases in wheat and barley (Saari and Prescott, 1975)

Key to Figure: Description of severity levels (Saari and Prescot, 1975)

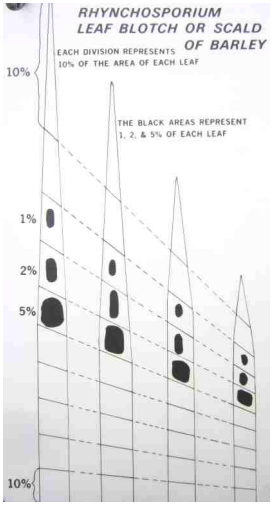
0	Free from infection.
0E	Free from infection, but probably represents an escape.
1	Resistant: A few isolated lesions on only the lowest leaves.
2	Resistant: Scattered lesions on the second set of leaves with first leaves lightly infected.
3	Resistant: Light infection of lower third of plant; lowermost leaves infected at moderate to severe levels.
4	Moderately resistant: Moderate infection of lower leaves with scattered to light infection extending to the leaf immediately below the middle of the plant.
5	Moderately susceptible: Severe infection of lower leaves; moderate to light infection extending only to the middle of the plant.
6	Moderately susceptible: Severe infection on lower third of plant, moderate on middle leaves and scattered lesions beyond the middle of the plant.
7	Susceptible: Lesions severe on lower and middle leaves with infection extending to the leaf below the flag leaf, or with trace infection on the flag leaf.
8	Susceptible: Lesions severe on lower and middle leaves; moderate to severe infection of upper third of plant; flag leaf infected in amounts more than a trace.

9 Highly susceptible: Severe infection on all leaves; spikes also infected to some degree.

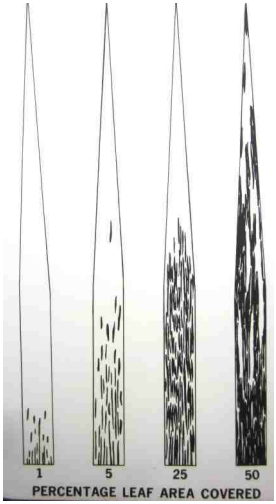
More advanced scoring is a double digit system (both the height and severity). Please refer to appendix 4 for details. If disease has reached 7 by height and 6 by severity then the total score is 76. The pictorial guide for estimating disease severity by James (1971) is given below.



Powdery mildew



Scald



Blotch or stripe

Based on the pictorial guide by James (1971), the following scale is suggested for measuring disease severity.

Scale	Leaf area covered by disease
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

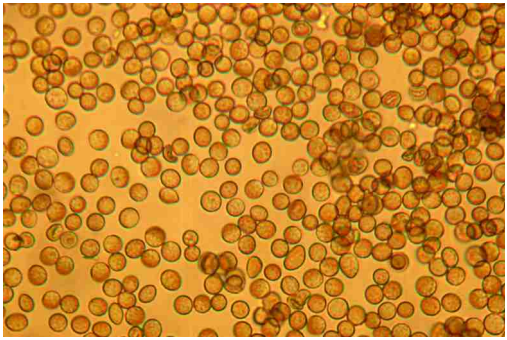
Disease

Loose smut (लुज स्मट / नाङ्गो कालोपोके)

Loose smut is a commonly occurring fungal disease of barley, both in the hills and terai. The disease is primarily seed-transmitted and the pathogen spreads from infected to healthy plants by air in the same season. The plants from healthy-looking infected seeds become diseased in the next season planting and the pathogen spreads to nearby plants.

Pathogen

Ustilago nuda



Credit: Shrinkhala Manandhar

Teliospores of *Ustilago nuda*

Identification

Masses of olive brown smut spores replace the entire head of plant with little development of floral bracts and awns. Smutted heads always emerges earlier than healthy heads. Spores are blown by wind when the membrane breaks and the naked rachis remains.

Credit: Hira Kaji Manandhar

Loose smut of barley

Scoring

Scale	Head infection
0	No disease observed
1	Less than 5%
3	6 to 10%
5	11 to 20%
7	21 to 40%
9	More than 40%

(Adopted from Sharma and Karki, 1994, described for loose smut of wheat)

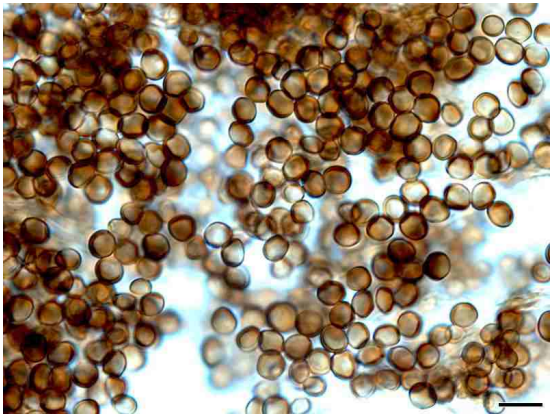
Disease

Covered smut (कभर्ड स्मट / ढाकिएको कालोपोके)

Covered smut is another commonly occurring fungal disease in all barley growing areas of Nepal. Its incidence is higher than loose smut. The pathogen is both seed borne and soil borne.

Pathogen

Ustilago hordei



Source: collections.daff.qld.gov.au/web/key/.../ustilagohordei.html

Teliospores of *Ustilago hordei*

Identification

Masses of dark brown spores replace the entire head of the plant. The kernels are completely replaced by black masses of teliospores covered by a silvery membrane. Floral bracts partially develop and spores remain inside a membrane until maturity. The spores are released during threshing and contaminate seed and soil.

Source: www.agric.wa.gov.au/mycrop/diagnosing-covered-smut-barley

Covered smut of barley

Scoring

Scale	Head infection
0	No disease observed
1	Less than 5%
3	6 to 10%
5	11 to 20%
7	21 to 40%
9	More than 40%

(Adopted from Sharma and Karki, 1994, described for loose smut of wheat)

References

Fetch, T. and Steffenson, B.J. 1999. Rating scale for assessing infection response of barley infected with *Cochliobolus sativus*. Plant Disease 83:213-217.

IPO and CIMMYT. Rust scoring guide research. Institute for Plant protection (IPO), Wageningen, The Netherlands and International Maize and Wheat Improvement Center (CIMMYT), Mexico.

James, W.C. 1971. A manual of assessment keys for plant diseases. Canada Department of Agriculture. Publication No. 1458. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, MN 55121 USA.

Mathre, D.E. ed. 1982. Compendium of barley diseases. APS Press. The Americn Phytopathological Society, Minnesota, USA.

Saari E.E. and Prescott, J.M. 1975. A scale for appraising the foliar intensity of wheat diseases. Plant Disease Reporter 59:377-380.

Sharma, S. and Karki, C.B. 1994. Identification of sources of resistance to loose smut of wheat. In: Proceedings of the National Conference on Science and Technology, pp. 189-196. Royal Nepal Academy of Science and Technology, Kathmandu, Nepal.

Steffenson, B., Pederson, J. and Pederson, V. 1999. Common barley diseases in North Dakota: hosts, symptoms and controls. PP-894 (Revised). North Dakota State University, Fargo, ND. Available at: https://www.ag.ndsu.edu/pubs/plantsci/smgrains/pp894.pdf.

Stubbs, R.W., Prescott, J.M. and Saari, E.E. 1986. Cereal disease methodology manual. International Maize and Wheat Improvement Center (CIMMYT) in cooperation with Research Institute for Plant Protection (IPO) Wageningen, The Netherlands.

Zadoks, J.C., Chang, T.T. and Konzak, C.F. 1974. A decimal code for the growth stage of cereals. Weed Research 14:415-421.

Zilllinsky, F.J. 1983. Common diseases of small grain cereals. International Maize and Wheat improvement Center, Mexico.

Chapter 3
Bean *(Phaseolus vulgaris* L.*)* Diseases

Disease

Root rot (रुट रट् / जरा कुहिने)

Root rot is one of the most common fungal diseases in most bean fields. The disease often causes moderate losses, but occasionally losses are severe. The root rot-causing fungi are soil borne and cause severe losses when plants are flooded or deprived of oxygen for some period.

Pathogen

***Fusarium solani, Rhizoctonia solani* and *Pythium* sp.**

Credit: Sharada Joshi

Micro and macroconidia of *Fusarium solani* (left); Hyphae of *Rhizoctonia solani* (center); Oospores of *Pythium* sp. (right)

Identification

Fusarium root rot: Plants are stunted or yellow, but not usually killed. The taproot and lower stem show reddish lesions, which later turn brown to black. The red-coloured taproot tip and lateral roots may decay, shrivel, and die. Rootlets may develop above the lesion, enabling the plant to survive.

Credit: Hira Kaji Manandhar

Fusarium root rot showing typical reddish discolouration in splitted lower stem and tap root of bean

Rhizoctonia root rot: Symptoms include seed rot and damping-off of seedlings, as well as stunting, yellowing, and death of older plants. Elongated, sunken, red-brown lesions develop on roots and lower stems at or below the soil surface. Infected plants may be stunted with yellow leaves and die. See web blight, also.

Source: www.industry.nsw.gov.au

Credit: Sharada Joshi

Typical Rhizoctonia root rot lesions (left), Rhizoctonia root rot (right) of bean

Pythium root rot: Elongated water-soaked areas on hypocotyls and roots are seen. These areas become slightly sunken with tannish-brown lesions that coalesce giving the entire root system and lower stem collapsed, shrunken appearance because of the wet soft rot. Rot of both primary and secondary roots takes place and the plant is greatly stunted or wilts and dies.

Credit: Sharada Joshi

Pythium root rot of bean

Scoring (at growth stages: V1, R6-R8), see appendix 3 for growth stages

Scale	Root parts affected
1	No visible disease symptoms.
3	Light discolouration either without necrotic lesions or with approximately 10% of the hypocotyl and root tissues covered with lesions.
5	Approximately 25% of the hypocotyl and root tissues covered with lesions but tissues remain firm with deterioration of the root system. Heavy discolouration symptoms may be evident.
7	Approximately 50% of the hypocotyls and root tissues covered with lesions combined with considerable softening, rotting, and reduction of root system.
9	Approximately 75% or more of the hypocotyl and root tissues affected with advanced stages of rotting, combined with severe reduction in the root system.

(Source: CIAT, 1987)

Alternatively,

Scale	Infected plants
1	0-5%
3	5-10%
5	21-40%
7	61-80%
9	100%

(Adopted from ICARDA International Nursery Guideline described for small grain legumes)

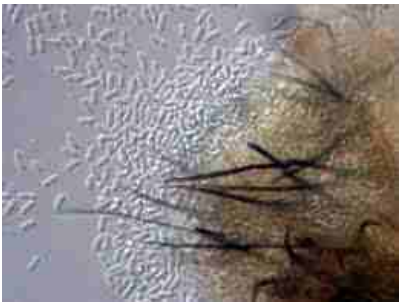
Disease

Anthracnose (एन्थ्राक्नोज / कोट्रे)

Anthracnose is one of the most important and widespread fungal diseases of beans in Nepal. It causes greater losses in the temperate and sub-tropical areas. The fungus is seed borne and survives in crop residue. Yield losses may reach 100% when infected seeds are planted and conditions are favourable to disease development.

Pathogen

Colletotrichum lindemuthianum



Source: www.insectimages.org/browse/detail.cfm?imgnum=5393376

Credit: Shrinkhala Manandhar

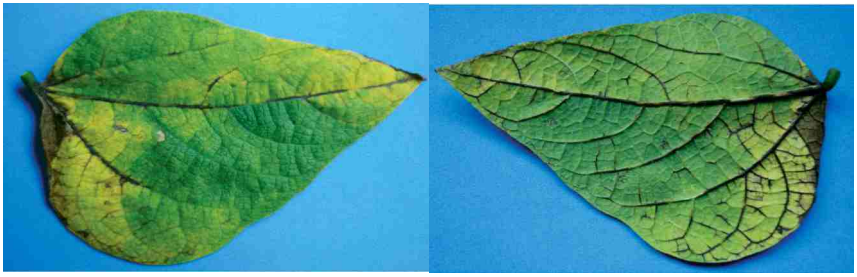
Conidia of *Colletotrichum lindemuthianum* released from acervuli, setae (left); and conidia (right)

Identification

Symptoms generally occur on the undersides of the leaves as linear, dark brick-red to black lesions on the leaf veins. As the disease progresses, the discolouration appears on the upper leaf surface.

http://www.gov.mb.ca/agriculture/crops/plant-diseases/print,anthracnose-dry-beans.html

Initial symptoms of anthracnose on the adaxial (left) and abaxial (right) surfaces of a bean leaf



Source:www.apsnet.org/publications/imageresources/Pages/FI000121.aspx

Severe symptoms of anthracnose on the adaxial (left) and abaxial (right) surfaces of a bean leaf

The most striking symptoms develop on the pods. Small, reddish-brown to black blemishes and distinct circular, reddish-brown lesions are typical symptoms. Mature lesions are surrounded by a circular, reddish-brown to black border with a grayish-black interior. During moist periods, the interior of the lesion may exude pink masses of spores. Severely infected pods may shrivel, and the seeds they carry are usually infected. Infected seeds have brown to black blemishes and sunken lesions.

Credit: Hira Kaji Manandhar

Anthracnose on bean pods

Scoring (at growth stage: R6-R8)

Scale	Plant parts affected
1	No visible disease symptoms.
3	Presence of very few and small lesions, mostly on the primary vein of the leaf's lower side or on the pod, that covers approximately 1% of the surface area.

Scale	Plant parts affected
5	Presence of several small lesions on the petiole or on the primary and secondary veins of the leaf's lower side. On the pods, small (less than 2 mm diameter) round lesions, with or without reduced sporulation, cover approximately 5% of the pod surface areas.
7	Presence of numerous enlarged lesions on the lower side of the leaf. Necrotic lesions can also be observed on the upper leaf surface and on petioles. On the pods the presence of medium-sized (larger than 2 mm in diameter) lesions are evident but also some small and larger lesions generally with sporulation and that cover approximately 10% of pod surface area may be found.
9	Severe necrosis on 25% or more of the plant tissue is evident as a result of lesions on the leaves, petioles, stem, branches, and even on the growing point which often results in death of the plant tissues. The presence of numerous, large, sporulating, sunken cankers can result in pod malformation, low seed number, and death of the pod.

(Source: CIAT, 1987)

Alternatively, for leaf infection

Scale	Plant parts affected
0	No disease
1	1-10% veins with lesions
2	11-25% veins and veinlets with lesions
3	26% or more veins and veinlets with lesions

(Source: Inglis et al., 1988)

Alternatively, for pod infection

Scale	Pod area covered with lesions
1	Less than 1%
2	1-10%
3	11-25%
4	26-50%
5	More than 50%

(Adopted from ICARDA International Nursery Guideline described for small grain legumes)

Disease

Angular leaf spot (एन्गुलर लिफ् स्पट / कोणाकार पाते थोप्ले)

Angular leaf spot is a widespread fungal disease of beans in Nepal. It is most common and destructive in areas where warm and moist conditions are prevalent. The fungus is seed borne and persists in infected plant residues.

Pathogen

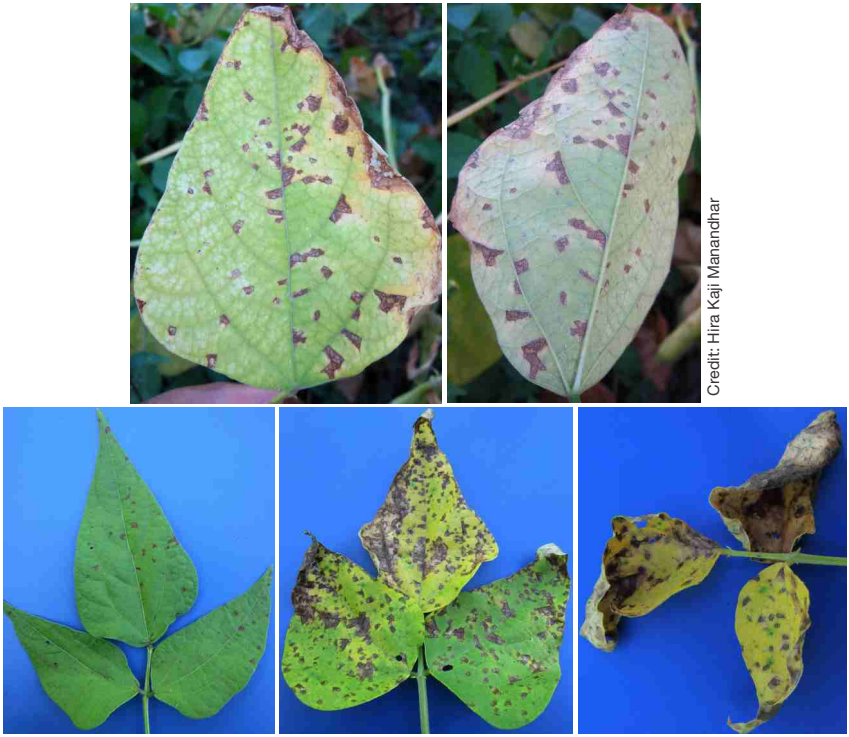
***Isariopsis griseola* (syn. *Phaeoisariopsis griseola*)**

Credit: Shrinkhala Manandhar

Synnemata (left) and conidia (right) of *Isariopsis griseola*

Identification

All aerial plant parts, including leaves, petioles, stems and pods can be infected, but symptoms are most recognizable on leaves. Lesions on leaves usually appear as brown spots with a tan or silvery centre that are initially confined to tissue between major veins, which gives it an angular appearance.



Credit: Hira Kaji Manandhar

Angular leaf spots on adaxial (upper left) and abaxial (upper right) leaf surface of bean, and different severities (lower left, center, and right, respectively)

Scoring (at growth stages: R6-R8)

Scale	Plant parts affected
1	No visible disease symptoms.
3	Presence of a few small nonsporulating lesions that cover approximately 2% of the leaf or pod surface area.
5	Presence of several, generally small lesions with limited sporulation that cover approximately 5% of the leaf or pod surface area.
7	Abundant and generally large sporulating lesions that cover approximately 10% of the leaf or pod surface area. On the foliage the lesions may coalesce to produce larger infected areas associated with chlorotic tissue. Lesions may also be found on the stem and branches.

Scale	Plant parts affected
9	Twenty-five percent or more of the leaf or pod surface area is covered by large sporulating and often coalescing lesions. Leaf tissues are generally chlorotic resulting in severe and premature defoliation. Infected pods are often deformed and shriveled and contain a low number of seeds. Abundant sporulating lesions are present on stem and branches.

(Source: CIAT, 1987)

Alternatively,

Scale	Plant parts affected
0	No disease
1	1-10% leaflet area with lesions
2	11-25% leaflet area with lesions
3	26-50% leaflet area with lesions and limited chlorosis
4	Over 50% or more of the leaflet area with lesions and extensive necrosis
5	Defoliation

(Source: Inglis et al., 1988)

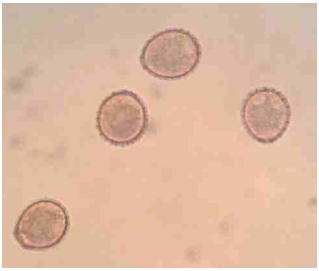
Disease

Rust (रस्ट / सिन्दुरे)

Rust is one of the most common and widespread fungal diseases of beans in Nepal. The disease is most prevalent in humid, temperate climates. Yield loss may reach 100%, depending on earliness and severity of infection.

Pathogen

***Uromyces appendiculatus* (syn. *U. phaseoli*)**

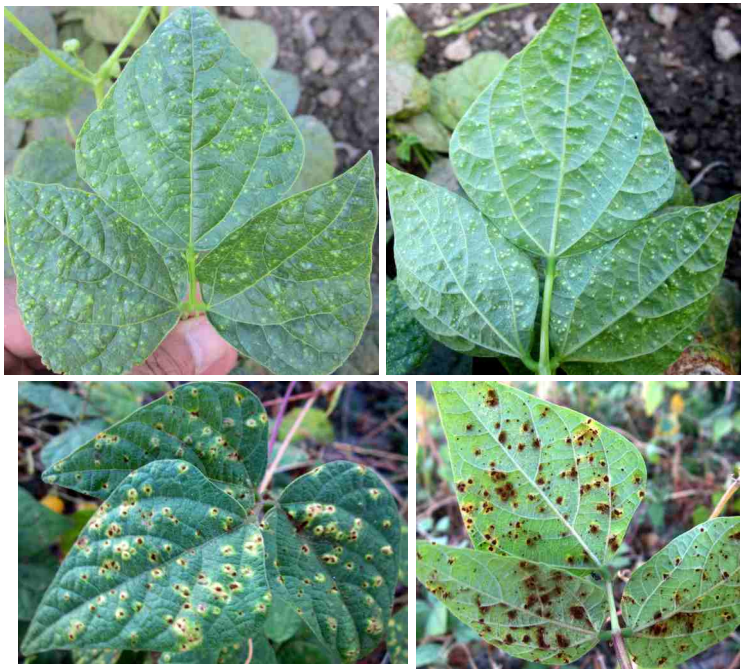


Credit: Ram Devi Timila

Uredospores of *Uromyces appendiculatus*

Identification

The common symptom of bean rust is the reddish brown, circular uredinial pustules on leaves that form 5-6 days after infection. Pustules enlarge slightly and rupture 7-9 days after infection to produce abundant powdery uredospores; black teliospores may also be produced. The pustules may vary in size from a pin point to 1-2 mm in diameter. Rust pustules tend to occur most numerously on leaf undersides, less abundantly on pods, and sparingly on stems.



Credit: Hira Kaji Manandhar

Early (upper) and developed (lower) rust pustules on adaxial and abaxial (left and right, respectively) leaf surfaces of bean

Scoring (at growth stages: R6-R8)

Scale	Plant parts affected
1	No visible rust pustule present.

Scale	Plant parts affected
3	Presence of only a few and generally small pustules on most plants that cover approximately 2% of the foliar areas.
5	Presence of generally small or intermediate pustules on all plants that cover approximately 5% of the foliar area.
7	Presence of mostly large pustules often surrounded by chlorotic halos that cover approximately 10% of the foliar area.
9	Presence of large and very large pustules, with chlorotic halos, that cover more than 25% of the foliar tissue and cause premature defoliation.

(Source: CIAT, 1987)

Alternatively,

Scale	Plant parts affected
0	No disease
1	1-10% leaflet area with lesions
2	11-25% leaflet area with lesions
3	26-50% leaflet area with lesions and limited chlorosis
4	Over 50% or more of the leaflet area with lesions and extensive necrosis
5	Defoliation

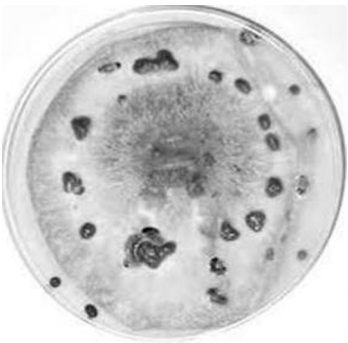
(Source: Inglis et al., 1988)

Disease

White mold (ह्वाइट मोल्ड / सेतो ढुसी)

White mold is one of the important fungal diseases of beans mostly found in the temperate areas of Nepal. It can affect all aerial parts of beans in the field, as well as green beans in transit and storage. Crop losses may reach 100%. The disease is typically serious in crops that have a dense canopy in field with a history of the disease, and in seasons when cool moist conditions occur during and after flowering.

Pathogen
Sclerotinia sclerotiorum



Source:http://www.invasive.org/browse/detail.cfm?imgnum=5363968

Asci containing ascospores (left) and culture with dark-coloured sclerotia (right) of *Sclerotinia sclerotiorum*

Identification

A watery, soft rot with white, fluffy fungal growth on above-ground plant parts are common. Small, solid, irregularly shaped sclerotia form in the white growth and inside the rotting tissue. A rapid rot develops on pods. The white mycelial growth and black sclerotia are very diagnostic.

Credit: Hira Kaji Manandhar

White mold on bean plants (left) and molds with sclerotia formation on pod (right)

Scoring (at growth stages: R8-R9)

Scale	Affected area
1	No visible disease symptoms.
3	Approximately 5%-10% of the unit area evaluated is infected.
5	Approximately 20%-30% of the unit area evaluated is infected.
7	Approximately 40%-60% of the unit area evaluated is infected.
9	More than 80% of the unit area evaluated is infected.

(Source: CIAT, 1987)

Alternatively,

Scale	Affected area
0	No visible symptoms
1	1-25%
2	26-50%
3	51-75%
4	>75% of stem rot area
5	Dead plants

(Adopted from ICARDA International Nursery Guideline described for small grain legumes)

Disease

Web blight (वेव ब्लाइट / डढुवा)

Web blight of beans is a destructive fungal disease in the humid lowlands of the tropics. The fungus is soil borne and survives as sclerotia or mycelium in soils. It also survives in infected plant debris and other host plants. See root rots, also.

Pathogen

Rhizoctonia solani (*Teleomorph: *Thanatephorus cucumeris)

Identification

Both the asexual and sexual (teleomorph) states of the fungus can infect the plant and cause different symptoms. Infections originating from sclerotia (asexual) appear as small necrotic spots (5-10 mm in diameter) with brown centers and olive green margins. The spots enlarge, become irregular and somewhat zonate, and coalesce. Infected leaves, petioles, flowers and pods become rapidly covered by small sclerotia and brown mycelium, and die within 3-6 days after infection. Leaves are held together by the mycelial growth of the fungus resulting in a web-like appearance.

Infections caused by basidiospores (sexual) appear as distinct, small necrotic, circular lesions 2-3 mm in diameter. They are light brown or brick red with a lighter-coloured center.

The fungus may attack pods in contact with the soil causing pod blight; a rapid transit rot with off-white fungal growth may develop in these pods.

Photo: José Galindo, source: http://www.tropag-fieldtrip.cornell.edu/Thurston_TA/ptapado.html

Credit: Sharada Joshi

Web blight of beans (left); symptoms on pods (right)

Scoring (at growth stages: R8-R9)

Scale	Affected area
1	No visible disease symptoms.
3	Approximately 5%-10% of the unit area evaluated is infected.

Scale	Affected area
5	Approximately 20%-30% of the unit area evaluated is infected.
7	Approximately 40%-60% of the unit area evaluated is infected.
9	More than 80% of the unit area evaluated is infected.

(Source: CIAT, 1987)

Alternatively,

Scale	Affected area
0	No visible symptoms
1	1-25%
2	26-50%
3	51-75%
4	>75% of stem rot area
5	Dead plants

(Adopted from ICARDA International Nursery Guideline described for small grain legumes)

Disease

Common bacterial blight (कमन व्याक्टेरियल व्लाइट / व्याक्टेरियल डढुवा)

Common bacterial blight is one of the major and widespread bean diseases. High humidity, rain or both favour rapid progress of the disease. Losses may range from 10 to 45%. The bacterium is seed borne and overwinters in infected plant debris in temperate regions.

Pathogen

Xanthomonas campestris* pv. *phaseoli

Source: www.springerplus.com/content/pdf/2193-1801-2-41.pdf

Bacterial colonies on media

Identification

Lesions on leaves first appear as small, water-soaked, light green areas often surrounded by a large yellow halo. Leaf spots become dry and brown with a narrow yellow halo. As the disease progresses, spots may expand, eventually killing leaves.

Similar water-soaked spots form on pods and can develop into broad irregular blotches. In humid weather, a yellow bacterial crust covers the surface of the diseased area. The margin of the spot or the entire spot may be red-brown in colour.

Source: www.generationcp.org/sunsetblog/tag/bean-stem-maggot/

Common bacterial blight symptom on bean leaves

Scoring (at growth stages: R6-R8)

Scale	Plant parts affected
1	No visible disease symptoms.
3	Approximately 2% of the leaf surface area covered with a few small lesions. Pods are generally free of lesions.
5	Approximately 5% of the leaf surface area covered by small lesions that are beginning to coalesce and sometimes encircled by yellow halos resulting in minor blight. Lesions on the pods are generally small and not coalescing.
7	Approximately 10% of the leaf surface area covered with medium and large lesions which are usually accompanied by yellow halos and necrosis. Lesions on pods are large and coalescing and often show bacterial exudate.

Scale	Plant parts affected
9	More than 25% of the leaf surface area with large coalescing and generally necrotic lesions resulting in defoliation. Lesions on pods coalesce to cover extensive areas, exhibit abundant bacterial exudation which sometimes causes pod malformation and empty pods.

(Source: CIAT, 1987)

Alternatively,

Scale	Leaf area affected
0	No visible disease symptoms.
1	Not more than 10% leaf surface is affected, leaves of the lower and partly middle part of the plant are damaged.
2	11-30% leaf surface is affected, leaves of the lower, middle and partly upper part of the plant are damaged.
3	30-50% leaf surface is affected, leaves of the all parts of the plant are damaged, spots on the stem are visible.
4	50% and more leaf surface is affected, leaves of the all parts of the plant are damaged, strips on the stem are visible.

(Source: Vishnyakova, 2001)

Disease

Halo blight (हालो ब्लाइट / हालो डढुवा)

Halo blight is a major bacterial disease of beans in Nepal. The disease is more destructive in areas where temperatures are moderate and abundant inoculum is available. The bacterium survives in seeds and crop debris, is spread by splashing water and soil movement and enters plants through natural openings such as stomata.

Pathogen

Pseudomonas syringae

Identification

Small water-soaked spots are seen on the underside of leaves, which turn necrotic and become visible on the upper surface. A zone of yellow-green tissue (halo) appears around the infection points. Lesions on expanding leaves may cause distorted leaves; red-brown lesions may be visible on pods; pod lesions may ooze or may turn tan in colour.

Photo: Kiran Ghising, Source: www.ag.ndsu.edu/cpr/plant-pathology/bacterial-blights-showing-up-on-dry-beans-08-22-13

Source:www.plantvillage.org/en/topics/bean/infos/diseases_and_pests_description_uses_propagation

Halo blight symptoms on bean leaves (left); Symptoms of halo blight on bean pods (right)

Scoring (at growth stages: R6-R8)

Scale	Plant parts affected
1	No visible disease symptoms.
3	Approximately 2% of the leaf or pod surface area covered with round lesions. Very slight systemic chlorosis may be evident.
5	Approximately 5% of the leaf or pod surface area covered with round lesions of about 5 mm in diameter. Limited systemic chlorosis may be present on growing points.
7	Approximately 10% of the leaf tissues affected either by lesions or by the resulting chlorosis. Limited leaf distortion is present and the pods generally show a bacterial exudation on coalescing lesions that can be about 10 mm in diameter.
9	Twenty-five percent or more of the leaf tissues affected by lesions and chlorosis. Severe leaf distortion and coalescing lesions covering large areas on pods cause deformation and empty pods.

(Source: CIAT, 1987)

Disease

Bean yellow mosaic (बिन यलो मोजाइक)

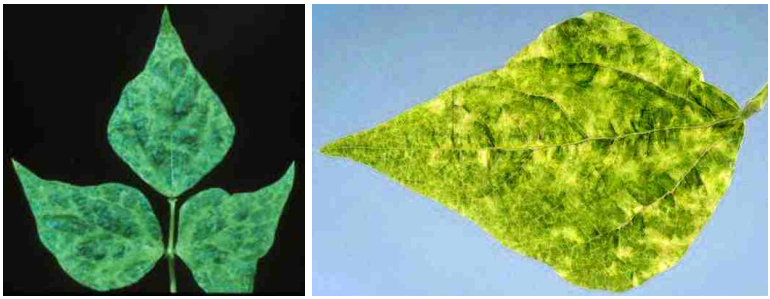
Bean yellow mosaic is a virus disease that is widely distributed on beans in Nepal. The virus is seed borne. Its host range includes bean, pea and several leguminous species. The disease has been reported to produce devastating epidemics, causing considerable losses in yield and quality of the bean crop, or to infect entire fields with only minor damage.

Pathogen

Bean Yellow Mosaic Virus (BYMV)

Identification

Symptoms generally include one or more of the following: crinkling, downward cupping, yellow mottling, and mosaic depending on time of infection, bean variety, and virus strain. Generally, late infection causes less prominent foliar symptoms, and pods infected while developing will exhibit a light green mottle and slight malformation.



Source:www.growingproduce.com/uncategorized/pest-of-the-month-yellow-bean-mosaic-virus; and http://wiki.bugwood.org/HPIPM:Bean_Yellow_Mosaic_Virus

Mosaic symptoms on bean leaves caused by *Bean Yellow Mosaic Virus*

Scoring

Scale	Symptom
1	No virus symptom seen
2	Occasional mild symptom
3	Moderate symptom

Scale	Symptom
4	Severe and wide spread symptom
5	Severe with likely loss in yield

(Adopted from AVRDC described for Mungbean Yellow Mosaic Virus)

Disease

Bean common mosaic (बिन कमन मोजाइक)

Bean common mosaic is a commonly occurring important virus disease of beans in Nepal. Yield losses may vary from 6 to 98% depending on the cultivar and time of infection. The virus is seed borne and transmitted by aphids. Host range is limited.

Pathogen

Bean Common Mosaic Virus (BCMV)

Identification

Light and dark green mosaic, leaf roll, malformation or yellow spots may be produced, often causing growth reduction. Severe vascular necrosis may also occur, and plants may die if infected while young. When infection occurs late in plant development, parts of the plant may die, and many pods, even on apparently healthy parts may show brown discolouration in the pod wall and pod sutures as a result of vascular necrosis.

Credit: Hira Kaji Manandhar

Mosaic symptoms on bean caused by *Bean Common Mosaic Virus*

Scoring

Scale	Symptom
1	No virus symptom seen
2	Occasional mild symptom
3	Moderate symptom
4	Severe and wide spread symptom
5	Severe with likely loss in yield

(Adopted from AVRDC described for Mungbean Yellow Mosaic Virus)

References

CIAT (Centro Internacional de Agricultura Tropical). 1987. Standard system for the evaluation of bean germplasm. van Schoonhoven, A., and Pastor-Corrales, M.A. (compilers). The International Center for Tropical Agriculture, Cali, Colombia.

Godoy, C.V., Carneiro, S.M.T.P.G., Iamauti, M.T., Pria, M.D., Amorim, L., Berger, R.D. and Filho, A.B. 1997. Diagrammatic scales for bean diseases: development and validation. Journal of Plant Diseases and Protection 104 (4):336-345.

Hall, R. ed. 1991. Compendium of bean diseases. APS Press. The American Phytopathological Society, Minnesota, USA.

Inglis, D.A., Haedorn, D.J. and Rand, R.E. 1988. Use of dry inoculum to evaluate beans for resistance to *anthracnose* and angular leaf spot. Plant Disease 72:771-774.

Vishnyakova, M. 2001. Evaluations of grain legumes germplasms of Vavilov Institute for disease resistance. "Standartization diseases resistance screening in grain legumes germplasm banks" Spain, Valodolid, 2001. P.1-8. (available at: http://vir.nw.ru/glycine/evalution.htm).

Seebold, K.W. 2014. Bean diseases. Plant Pathology Fact Sheet, PPFS-VG-16. University of kentucky, USA. (available at: http://www2.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-VG-16.pdf).

Chapter 4
Common Buckwheat *(Fagopyrum esculentum* Moench*)* and Bitter Buckwheat [*Fagopyrum tataricum* (L.) Gaertn] Diseases

Disease

Damping-off (ड्याम्पीङ अफ् / बेर्ना कुहिने) **and *Root rot*** (रुट रट् / जरा कुहिने)

Damping-off and root rot are common fungal diseases of buckwheat. The diseases are mostly soil borne. Wet soils favour the disease.

Pathogen

***Rhizoctonia solani, Pythium* spp., *Fusarium* spp.**

Identification

Damping-off causes failure of seedlings to emerge when infection occurs soon after planting. Affected seedlings have light brown to red water-soaked roots and stems, which later results in drying and collapse of plants.

Root rot on older plants results in stunting and yellowing of leaves. The lower stem and roots are discoloured and decayed showing various symptoms depending on the fungi causing rot.

Credit: Hira Kaji Manandhar

Died/dried plants in the field due to root rot (left) and root rot symptoms on uprooted plants of buckwheat (right)

Scoring

Count the number of infected seedlings per unit area and calculate the percentage infection.

Disease

Powdery mildew (पाउडरी मिल्ड्यू / धुले ढुसी)

Powdery mildew is a commonly occurring major fungal disease of buckwheat. The fungus is also reported as seed borne.

Pathogen

Erysiphe polygoni

Identification

Symptoms appear as light-coloured blotches on the leaves. These blotches expand in size and become more apparent during seed fill and may even result in small necrotic areas.

Credit: Hira Kaji Manandhar

Credit: Suk Bahadur Gurung

Symptoms of powdery mildew; initial starting from leaf edges (left), heavily infected both leaf and stem (middle); covering whole leaf of common buckwheat

Scoring

Scale	Area plants parts infected
0	No lesion
1	10% of plant parts infected
2	20% of plant parts infected
3	30% of plant parts infected
4	40% of plant parts infected
5	50% of plant parts infected

Scale	Area plants parts infected
6	60% of plant parts infected
7	70% of plant parts infected
8	80% of plant parts infected
9	90% of plant parts infected

(Source: Hill Crops Research Program, Nepal)

Alternatively,

Scale	Leaf area infected
0	No infection
1	Up to 25% leaf area infected
2	26-50% leaf area infected
3	More than 50% leaf area infected

(Source: Zimmer, 1984)

Disease

Downy mildew (डाउनी मिल्ड्यू)

Downy mildew is a major fungal disease of buckwheat. It occurs in all buckwheat growing areas, especially the high hills. The fungus has also been reported as seed borne.

Pathogen

Perenospora fagopyri

Source: http://agra.com.ua/field/123.htm

Oospores of *Peronospora fagopyri*

Identification

Large circular, chlorotic lesions occur on leaves, generally on the uppermost leaves. As the disease progresses, systemic infection occurs causing shortened internodes on upper stems of some plants and epinasty (bending downward) of leaves. Some leaves that are badly infected have a mosaic-like appearance.

Conidia and conidiophores occur on lower leaf surfaces. Clumped conidia are purplish and can be seen with naked eye. On seedlings, leaves are rugose and mottled. Seedlings are stunted with small stem diameter.

Credit: Hira Kaji Manandhar

Symptoms of downy mildew on upper (left) and lower (right) leaf surfaces of buckwheat

Scoring

Scale	Area plants parts infected
0	No lesion
1	10% of plant parts infected
2	20% of plant parts infected
3	30% of plant parts infected
4	40% of plant parts infected
5	50% of plant parts infected
6	60% of plant parts infected

Scale	Area plants parts infected
7	70% of plant parts infected
8	80% of plant parts infected
9	90% of plant parts infected

(Source: Hill Crops Research Program, Nepal)

Alternatively,

Scale	Leaf area infected
0	No infection
1	Up to 25% leaf area infected
2	26-50% leaf area infected
3	More than 50% leaf area infected

(Source: Zimmer, 1984)

Disease

Rust (रस्ट / सिन्दुरे)

Rust is a commonly occurring fungal disease of buckwheat, especially in the high hills. The disease also has been found in wild buckwheat plants.

Pathogen

Puccinia fagopyri

Credit: Sharada Joshi

Credit: Suk Bahadur Gurung

Uredospores of *Puccinia fagopyri*

Identification

The most common symptom of rust on buckwheat is yellow spots that appear on upper leaf surface and reddish-brown uredinial pustules on lower leaf surface, which rupture the epidermis to produce powdery spores.

Credit: Suk Bahadur Gurung

Symptoms of rust on the upper (left and center) and lower leaf surface (right) of buckwheat

Scoring

Scale	Plant parts affected
0	No disease
1	1-10% leaflet area with lesions
2	11-25% leaflet area with lesions
3	26-50% leaflet area with lesions and limited chlorosis
4	Over 50% or more of the leaflet area with lesions and extensive necrosis
5	Defoliation

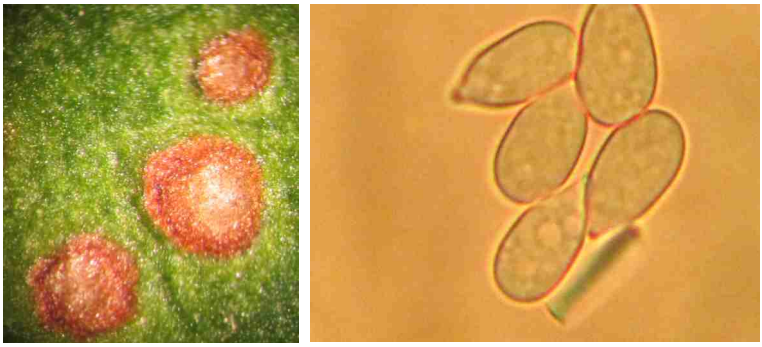
(Adopted from Inglis et al., 1988, described for bean diseases)

Disease

Botrytis leaf blight (बोट्राइटिस लिफ् व्लाइट / बोट्राइटिस पात डढुवा)

Botrytis leaf blight is a minor fungal disease in Nepal. The fungus is seed borne and survives mainly in infected plant debris and other host plants. The disease was identified for the first time from Pakhribas, Dhankuta in 2015.

Pathogen
Botrytis cinerea



Credit: Sharada Joshi

Sporulation of *Botrytis cinerea* on blighted leaf (left) and conidia (right)

Identification

Reddish-brown spots appear on leaves, which coalesce and become blighted and necrotic.

Credit: Sharada Joshi

Botrytis leaf blight of buckwheat

Scoring

Scale	Leaf area affected
1	No spot visible
3	Few scattered spots
5	Spots common on leaves and easily observed but causing no apparent damage
7	About 70% leaf area covered with spots
9	90% leaf area damaged, spots on pods and stems

(Adopted from ICARDA International Nursery Guideline described for small grain legumes)

References

Inglis, D.A., Haedorn, D.J. and Rand, R.E. 1988. Use of dry inoculum to evaluate beans for resistance to *anthracnose* and angular leaf spot. Plant Disease 72:771-774.

Milevoj, L. 1989. Buckwheat diseases. Fagopyrum 9:31-40.

Zimmer, R.C. 1974. Chlorotic leafspot and stipple spot, newly described diseases of buckwheat in Manitoba. Canadian Plant Disease Survey 54(2):55-56.

Zimmer, R.C. 1984. Incidence and severity of downy mildew of buckwheat in Manitoba. Canadian Plant Disease Survey 64(2):25-27.

Buckwheat (available at: https://www.plantvillage.com/en/topics/buckwheat/infos/diseases_and_pests_description_uses_propagation).

Chapter 5
Finger Millet [*Eleusine coracana* (L.) Gaertn] Diseases

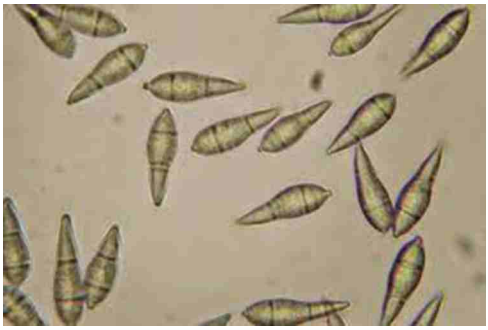
Disease

Blast (ब्लाष्ट / मरुवा)

Blast is an economically important and widespread fungal disease of finger millet in Nepal. It is seed borne and overwinters in infected crop debris. It damages the foliage, neck and finger at different growth stages of the crop. Infection prior to milking stage causes greater reduction in yield. Lower temperatures with more than 70% humidity favours disease development and may cause epidemics of leaf blast, neck blast or finger blast.

Pathogen

***Pyricularia grisea* (Teleomorph: *Magnaporthe grisea*)**



Source: www.cal-ipc.org

Conidia of *Pyricularia grisea*

Identification

Leaf blast appears on leaves as small brown spots. Typical lesions are elliptical or diamond-shaped, with grey centers, water-soaked and surrounded by a chlorotic halo.

Neck blast is characterized by the appearance of brown lesions in the neck region. Lesions later girdle the neck. As the disease progresses, the affected portion may rot or dry out causing spikelet sterility.

Finger blast appears as a discolouration of the fingers that dry prematurely to various degrees. The infected fingers may be shriveled with sterile grains depending on the time of infection.

Credit: Hira Kaji Manandhar

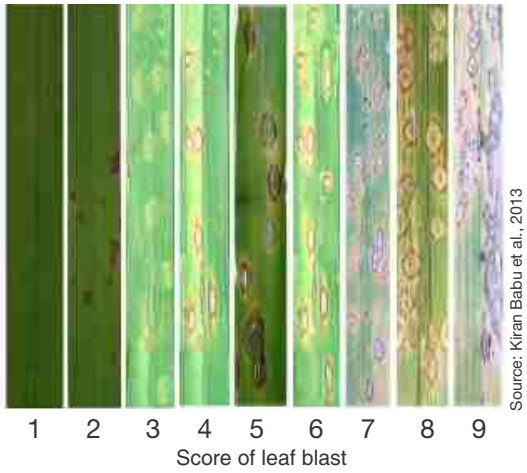
Leaf blast (left), neck blast (center) and finger blast (right) of finger millet

Scoring

For leaf blast (Seedling and booting stage)

Scale	Leaf area percent covered
1	No lesions, or small brown specks of pinhead size (0.1-1.0 mm), less than 1% leaf area affected
2	Typical blast lesions covering 1-5% leaf area covered
3	6-10% leaf area covered by typical blast lesions
4	11-20% leaf area covered by typical blast lesions
5	21-30%, leaf area covered by typical blast lesions
6	31-40%, leaf area covered by typical blast lesions
7	41-50%, leaf area covered by typical blast lesions
8	51-75%, leaf area covered by typical blast lesions
9	Typical blast lesions covering >75% leaf area or all the leaves dead

(Source: Kiran Babu et al., 2013)



For neck blast

Scale	Lesion size on the neck
1	No lesions to pin head size of lesions
2	0.1 to 2.0 cm size of typical blast lesion on the neck region
3	2.1 to 4.0 cm size of typical blast lesion on the neck region
4	4.1 to 6.0 cm size of typical blast lesion on the neck region
5	> 6.0 cm size of typical blast lesion on the neck region

(Source: Kiran Babu et al., 2013)

For finger blast

Scale	Percent ear or finger affected
0	No incidence
1	0.1-2%
2	2.1-10%
3	10-25 %
4	25.1-50%
5	> 50 %

(Source: Kiran Babu et al., 2013)

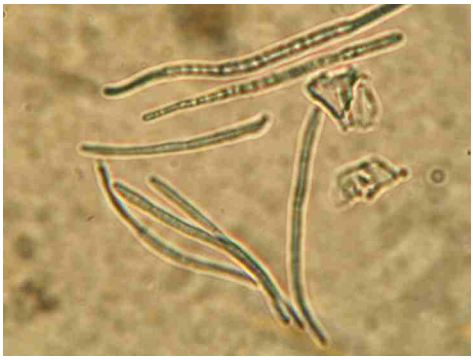
Disease

Cercospora leaf spot (सर्कोस्पोरा लिफ स्पट / सर्कोस्पोरा पाते थोप्ले)

Cercospora leaf spot is the second most important fungal disease of finger millet in Nepal. The disease is widespread and appears on lower leaves late in the season. Disease emergence occurs when high temperatures coincide with periods of high humidity. The fungus is seed borne and persists on crop residues and weed plants. The disease generally causes little yield loss since symptoms develop late in the growing season.

Pathogen

Cercospora eleusine



Credit: Ram Devi Timila

Conidia of *Cercospora eleusine*

Identification

Initial symptoms appear as dark, small and oval spots, later they may become oblong to rectangular in shape. Lesions or spots tend to have pale-tan to gray centers with prominent black dots (fungal fruiting structures), and may be covered with a silvery layer of spores during wet weather. Stem lesions are similar to leaf lesions, but tend to be longer.

Credit: Hira Kaji Manandhar

Light to severe infection of Cercospora leaf spot on finger millet leaves

Scoring

Scale	Leaf area percent covered
1	No lesions to small brown specks of pinhead size (0.1-1.0 mm), less than 1% leaf area affected
2	Typical lesions/spots covering 1-5% leaf area
3	6-10% leaf area covered by lesions
4	11-20% leaf area covered by lesions
5	21-30%, leaf area covered by lesions
6	31-40%, leaf area covered by lesions
7	41-50%, leaf area covered by lesions
8	51-75%, leaf area covered by lesions
9	>75% leaf area or all the leaves dead

(Source: Kiran Babu et al., 2013)

Disease

Sheath blight (शीथ ब्लाइट / पाते फेद डढुवा)

Sheath blight is a minor fungal disease of finger millet though it may become severe under conducive conditions. A temperature of around 28-30°C and relative humidity of 70% or above favour rapid disease development. The disease is soil borne and can be spread easily causing considerable crop loss. The disease was found at Pokhara for the first time in 2015.

Pathogen

Rhizoctonia solani

Credit: Ram Devi Timila

Hyphae of *Rhizoctonia solani*

Identification

Symptoms appear as oval to irregularly shaped light-grey to dark brown lesions on the leaf sheath. The centers of the lesions later turn white to straw colour with narrow, reddish-brown borders, which may appear as bands across the leaf sheaths. Lesions at first appear on the sheaths of leaves near soil level but rapidly extend, and coalesce covering large portions of the sheath and leaves giving a blighted appearance.

Credit: Ram Devi Timila

Typical banded blight symptom on finger millet leaves

Scoring

Scale	Plant parts affected
0	No infection
1	Lesions limited to lower 20% of the plant height
3	Lesions limited to lower 20 to 30% of the plant height
5	Lesions limited to lower 31 to 45% of the plant height
7	Lesions limited to lower 46 to 65% of the plant height
9	Lesions more than 65% of the plant height

(Source: Patro and Madhuri, 2014)

References

Kiran Babu, T., Thakur, R.P., Upadhyaya, H.D., Reddy, P.N., Sharma, R., Girish, A.G. and Sarma, N.D.R.K. 2013. Resistance to blast (*Magnaporthe grisea*) in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology 135(2):299-311.

Hunsigi, G. and Krishna, K.R. 1998. Science of field crop production; Finger millet, New Delhi Oxford and IBH publishing Co Pvt. ltd., pp 132.

Nagraja, A. and Reddy, B.A. 2010. Banded blight - a new record on finger millet in Karnataka. Journal of Mycopathological Research 48(1):169-170.

CABI. 2008. *Eleusine coracana* datasheet. Crop Protection Compendium. (available at: http://www.cabi.org/cpc/datasheet/20674.

Patro, T.S.S.K. and Madhuri, J. 2014. Epidemiological studies on blast disease of finger millet (*Eleusine coracana* (L) Gaertn.) incited by *Pyricularia grisea* (Cke) Sacc. Indian Journal of Plant Sciences 3(1):115-117.

Patro, T.S.S.K. and Madhuri, J. 2014. Identification of resistant sources for sheath blight in foxtail millet incited by *Rhizoctonia solani* Kuhn. Indian Journal of Plant Sciences 3(2):159-162.

Patro, T.S.S.K. and Madhuri, J. 2014. Identification of resistant varieties of finger millet for leaf, neck and finger blast. International Journal of Food, Agriculture and Veterinary Sciences 4(2):7-11.

[1]https://www.google.com.np/search?q=bipolaris+nodulosa&biw=1366&bih=657&source=lnms&tbm=isch&sa=X&ved=0ahUKEwix0_OAwtTJAhVM1RQKHdXYDeMQ_AUIBigB#imgrc=PNAh8wEhZvN78M%3A

[2]https://www.google.com.np/search?q=bipolaris+nodulosum&biw=1366&bih=657&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj7h9ramdfJAhWGyRQKHcYbBscQ_AUIBigB#tbm=isch&q=helminthosporium++nodulosum&imgrc=J1WDSnAjAIPVvM%3A

Chapter 6
Foxtail Millet [*Setaria italica* (L.) Beauv] Diseases

Disease

Blast (ब्लाष्ट / मरुवा)

Blast is a major fungal disease of foxtail millet. The fungus is seed borne and also survives in crop debris and other grass hosts.

Pathogen

Pyricularia setariae

Credit: Shrinkhala Manandhar

Conidia of *Pyricularia setariae*

Identification

Symptoms appear as circular spots with straw-coloured centers on leaf blades. The spots are small (2 to 5 mm in diameter), and surrounded by a dark brown margin. Under humid weather conditions, the lesions enlarge and coalesce with each other and the leaves wither and dry. Lower leaves are the most severely affected. The pathogen attacks the leaves, stem, neck and spike.

Credit: Suk Bahadur Gurung

Leaf blast of foxtail millet

Scoring

Leaf blast

Scale	Leaf area percent covered
1	No lesions, or small brown specks of pinhead size (0.1-1.0 mm), less than 1% leaf area affected
2	Typical blast lesions covering 1-5% leaf area covered
3	6-10% leaf area covered by typical blast lesions
4	11-20% leaf area covered by typical blast lesions
5	21-30%, leaf area covered by typical blast lesions
6	31-40%, leaf area covered by typical blast lesions
7	41-50%, leaf area covered by typical blast lesions
8	51-75%, leaf area covered by typical blast lesions
9	Typical blast lesions covering >75% leaf area or all the leaves dead

(Adopted from Kiran Babu et al., 2013, described for finger millet blast)

Neck/sheath blast

Scale	Lesion size on the neck or sheath region
1	No lesions to pinhead sized lesions
2	0.1-1 cm
3	1.1-2 cm
4	2.1-4.0 cm
5	> 4 cm

(Source: Sharma et al., 2014)

Head blast is recorded as a percentage of infected panicles at maturity (Sharma et al., 2014).

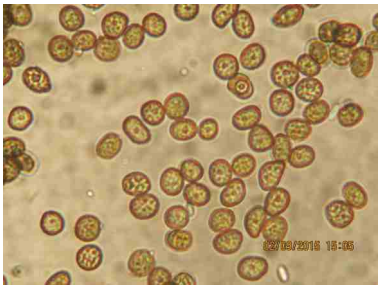
Disease

Smut (स्मट / कालोपोके)

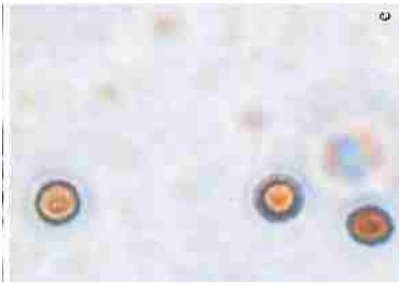
Smut is an important fungal disease of foxtail millet. The fungus is seed borne.

Pathogen

Ustilago crameri



Credit: Ram Devi Timila



Source: Kumar, 2011

Teliospores of *Ustilago crameri* (left); Teliospores showing echinulated surface of the smut spores (right)

Identification

The symptoms appear at the time of ear formation. Pale grayish to dark brown discolouration appears in the flowers initially, and later turns black. It produces sori in the flowers and basal parts of the palea. After the sori rupture, dark-black powdery masses of spores can easily be seen on the infected ear heads.

Credit: Suk Bahadur Gurung

Credit: Ram Devi Timila

Smutted heads (left), and a smutted spike (right) of foxtail millet under the stereomicroscope

Scoring

Disease rating is done as percent of spike infection over the total number of plants observed per unit area.

$$\text{Percent of spike infection (\%)} = \frac{\text{Number of infected spike}}{\text{Total number of observed spike}} \times 100$$

Scale	Head infection
0	No disease observed
1	Less than 5%
3	6 to 10%
5	11 to 20%
7	21 to 40%
9	More than 40%

(Adopted from Sharma and Karki, 1994, described for loose smut of wheat)

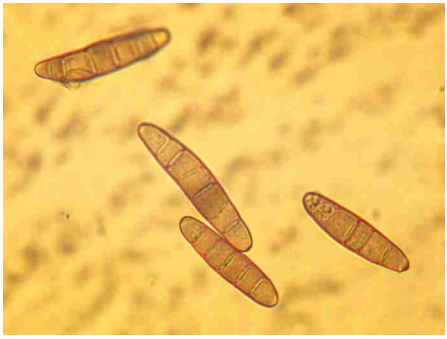
Disease

Blight (ब्लाइट / डढुवा)

Blight symptoms are occurred commonly in foxtail millet.

Pathogen Isolated

***Bipolaris* sp. (syn. *Helminthosporium* sp.)**



Credit: Shrinkhala Manandhar

Conidia of *Bipolaris* sp.

Identification

Necrotic symptoms on leaf, sheath and stem are found. Lesions coalesce causing leaves blighted.

Credit: Shrinkhala Manandhar

Necrotic lesions on leaves of foxtail millet

Scoring

Leaf blight

Scale	Infected leaf area
0	No incidence
1	Less than 1 % leaf area affected
2	1-3 % leaf area affected
3	4-5% leaf area affected
4	6-10 % leaf area affected
5	11-15 % leaf area affected
6	16-25 % leaf area affected
7	26-50 % leaf area affected
8	51-75 % leaf area affected
9	76-100% leaf area affected

(Adopted from IRRI, 2002, described for brown spot of rice)

References

IRRI. 2002. Standard evaluation system for rice. International Rice Research Institute. Manila Phillipines.

Kiran Babu, T., Thakur, R.P., Upadhyaya, H.D., Reddy, P.N., Sharma, R., Girish, A.R. and Sarma, N.D.R.K. 2013. Resistance to blast (*Magnaporthe grisea*) in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology 135(2):299-311.

Kumar, B. 2011. First record of smut disease of foxtail millet caused by *Ustilago crameri* Korn. Journal of Mycology and Plant Pathololgy 41(3):459-461.

Sharma, R., Girish, A.G., Upadhyaya, H.D., Humayun, P., Babu, T.K., Rao, V.P. and Thakur, R.P. 2014. Identification of blast resistance in a core collection of foxtail millet germplasm. Plant Disease 98:519-524.

Sharma, S. and Karki, C.B. 1994. Identication of sources of resistance to loose smut of wheat. In: Proceedings of the National Conference on Science and Technology, pp. 189-196. Royal Nepal Academy of Science and Technology, Kathmandu, Nepal.

Diseases of foxtail millet (available at: http://www.naro.affrc.go.jp/org/nilgs/diseases/contents/de40.htm).

Chapter 7
Proso Millet (*Panicum miliaceum* L.) Diseases

Disease

Blast (ब्लाष्ट / मरुवा)

Blast is an economically important fungal disease of proso millet. The fungus is seed borne and persists in stubble and weed hosts.

Pathogen

***Pyricularia grisea* (Teleomorph: *Magnaporthe grisea*)**

Credit: Hira Kaji Manandhar

Leaf blast (left) and panicle blast (right) of proso millet

Identification

Blast symptoms on leaves and panicles are similar to rice blast. Blast lesions on leaves appear as elliptical or diamond-shaped with grey center. The lesions turn brown upon drying.

Scoring

Leaf blast

Scale	Leaf area percent covered
1	No lesions, or small brown specks of pinhead size (0.1-1.0 mm), less than 1% leaf area affected
2	Typical blast lesions covering 1-5% leaf area covered
3	6-10% leaf area covered by typical blast lesions
4	11-20% leaf area covered by typical blast lesions
5	21-30%, leaf area covered by typical blast lesions

Scale	Leaf area percent covered
6	31-40%, leaf area covered by typical blast lesions
7	41-50%, leaf area covered by typical blast lesions
8	51-75%, leaf area covered by typical blast lesions
9	Typical blast lesions covering >75% leaf area or all the leaves dead

(Source: Kiran Babu et al., 2013)

Neck blast

Scale	Lesion size on the neck or sheath region
1	No lesions to pinhead sized lesions
2	0.1-1 cm
3	1.1-2 cm
4	2.1-4.0 cm
5	> 4 cm

(Source: Sharma et al., 2014)

Head blast is recorded as a percentage of infected panicles at maturity (Sharma et al., 2014).

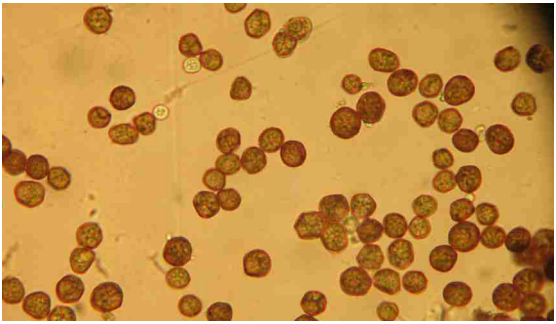
Disease

Head smut (हेड स्मट / कालोपोके)

Head smut is a widespread and an important fungal disease of proso millet. The fungus is seed borne. The disease was found for the first time in Humla.

Pathogen

Sphacelotheca destruens



Credit: Ram Devi Timila

Teliospores of *Sphacelotheca destruens*

Identification

Masses of black spores appear in place of spikelets. The inflorescence is replaced by sori, which are grayish-white or creamy coloured structures surrounded by a tough membrane of fungal tissue. Dark brown spore masses appear surrounding numerous fibers (vascular tissue) of host tissue. Sori remain within leaf sheaths covered by a gray white membrane until maturity.

Credit: Hira Kaji Manandhar

Head smut of proso millet showing black mass of spores with fibers in the spikelet

Scoring

Disease rating is done as incidence (percent) of spike infection over the total number of plants observed per unit area.

Disease

Blight (व्लाइट / डढुवा)

Blight symptoms are occurred commonly in foxtail millet.

Pathogen

***Bipolaris* sp.**

Credit: Shrinkhala Manandhar

Conidia of *Bipolaris* isolated from leaf of foxtail millet

Identification

Necrotic symptoms on leaf, sheath and stem are found.

Credit: Hira Kaji Manandhar

Large necrotic lesion on leaf (upper) and dark brown lesions on stem (lower) of proso millet

Scoring

Scale	Infected leaf area
0	No incidence
1	Less than 1 % leaf area affected
2	1-3 % leaf area affected
3	4-5% leaf area affected
4	6-10 % leaf area affected
5	11-15 % leaf area affected
6	16-25 % leaf area affected
7	26-50 % leaf area affected
8	51-75 % leaf area affected
9	76-100% leaf area affected

(Adopted from IRRI, 2002, described for brown spot of rice)

References

IRRI. 2002. Standard evaluation system for rice. International Rice Research Institute. Manila, Philippines.

Kiran Babu, T., Thakur, R.P., Upadhyaya, H.D., Reddy, P.N., Sharma, R., Girish, A.G. and Sarma, N.D.R.K. 2013. Resistance to blast (*Magnaporthe grisea*) in a mini-core collection of finger millet germplasm. European Journal of Plant Pathology 135(2):299-311.

Sharma, R., Girish, A.G., Upadhyaya, H.D., Humayun, P., Babu, T.K., Rao, V.P. and Thakur, R.P. 2014. Identication of blast resistance in a core collection of foxtail millet germplasm. Plant Disease 98:519-524.

Singh, R.S. and Prasad, Y. 1981. Blast of proso millet in India. Plant Disease 65:442-443.

Chapter 8
Rice *(Oryza sativa* L.*)* Diseases

Disease

Blast (ब्लाष्ट / मरुवा)

Blast is the most destructive fungal disease of rice worldwide. The pathogen can infect all parts of the shoot from seedling to maturity stage. Early infection of rice panicles causes severe reduction in grain yield. The pathogen is seed borne and overwinters in infected crop debris.

Pathogen

Pyricularia oryzae (*Teleomorph: *Magnaporthe oryzae)

Credit: Gyanu Manandhar, NARC

Conidia of *Pyricularia oryzae*

Identification

Initial symptoms on the leaves appear as white to gray-green lesions or spots, with dark green borders. Older lesions are elliptical or spindle-shaped having whitish to gray centers and red to brownish or necrotic borders. Some lesions are diamond-shaped, wide in the center and pointed toward either both ends. For beginners, blast lesions can commonly be confused with brown spot lesions; however, the latter tend to be more round, brown in colour and have a yellow halo surrounding the lesion.

Collar blast

Old lesions

Spindle-shaped lesions

Source:www.knowledgebank.irri.org/index.php?option=com_zoo&task=item&item_id=808&Itemid=739

Diamond-shaped lesions

Blast lesions on the node are blackish to grayish-brown covering around the node, causing the culm to break easily. Lesions on the neck are grayish brown and can cause girdling. If infection of the neck occurs before milky stage, no grain is formed, but if infection occurs later, lower weight and poor quality grains are formed. On susceptible varieties lesions can enlarge and coalesce, growing together, to kill the entire leaves.

Neck and node blast can also cause whiteheads or white panicles, similar to stem borer infection. Whiteheads caused by stem borers can be pulled apart from the plant as the stem will

separate at the point where the insect bored into it. With neck and node blast, tugging on the stem will not result in removal.

Credit: Hira Kaji Manandhar

Credit: Anju Pandey

Leaf blast (left), neck blast (center) and node blast (right) of rice

Scoring

For leaf blast nursery only (at Growth Stage 2-3) (see appendix 1 for growth stages)

Scale	Lesion type and affected leaf area
0	No lesions observed
1	Small brown specks of pin-point size or larger brown specks without sporulating center
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin
3	Lesion type is the same as in scale 2, but a significant number of lesions on the upper leaves
4	Typical susceptible blast lesions, 3 mm or longer, infecting less than 4% of the leaf area
5	Typical blast lesions infecting 4-10% of the leaf area
6	Typical blast lesions infection 11-25% of the leaf area
7	Typical blast lesions infection 26-50% of the leaf area
8	Typical blast lesions infection 51-75% of the leaf area and many leaves are dead
9	More than 75% leaf area affected

(Source: IRRI, 2002)

NOTE: Use this scale only for the nursery. Actual estimation of blast affected leaf area (%) is recommended for field assessment of blast disease together with predominant lesion type (see coding system for lesion type). Entries with consistent rating, between 4 and 6 with overall average not higher than 5.5 may have a good level of quantitative (partial) resistance.

Code (Predominant lesion type)

Scale	Lesion type
0	No lesions observed
1	Small brown specks of pinpoint size or larger brown specks without sporulating center
3	Small, roundish to slightly elongated necrotic sporulating spots, about 1-2 mm in diameter with a distinct brown margin or yellow halo
5	Narrow or slightly elliptical lesions, 1-2 mm in breadth, more than 3 mm long with a brown margin
7	Broad spindle-shaped lesion with yellow, brown, or purple margin
9	Rapidly coalescing small, whitish, grayish, or bluish lesions without distinct margins

(Source: IRRI, 2002)

For panicle blast - At growth stage: 8 (dough stage, 20-25 days after heading)

Based on the number of panicles with each scale, compute panicle blast severity (PBS) as follows:

$$PBS = \frac{(10xN_1)+(20 \times N_3)+(40xN_5)+(70xN_7)+(100xN_9)}{\text{Total no. of panicles observed}}$$

where N_1-N_9 are the number of panicles with score 1-9.

Scale	Panicle infection (based on symptoms)
0	No visible lesion or observed lesions on only a few pedicels
1	Lesions on several pedicels or secondary branches
3	Lesions on a few primary branches or the middle part of panicle axis
5	Lesion partially around the base (node) or the uppermost internode or the lower part of panicle axis near the base
7	Lesion completely around panicle base or uppermost internode or panicle axis near base with more than 30% of filled grains
9	Lesion completely around panicle base or uppermost internode or the panicle axis near the base with less than 30% of filled grains

(Source: IRRI, 2002)

For the mass evaluation of panicle blast incidence (at growth stage 8-9, dough to maturity)

Count only the number of panicles with lesions covering completely around the node, neck or lower part of the panicle axis (symptom type 7-9).

Scale	Number of infected panicles (node, neck or lower part of the panicle axis)
0	No incidence
1	Less than 5%
3	5-10%
5	11-25%
7	26-50%
9	More than 50%

(Source: IRRI, 2002)

Disease

Brown spot (ब्राउन स्पट / खैरो थोप्ले)

Brown spot is a major fungal disease of rice worldwide. It causes both quantity and quality losses. The fungus is seed borne and overwinters in infected crop debris. Though the disease is known to be prevalent mostly in nutrient-deficient soils, these days it has become more severe in wet and humid environments in Nepal.

Pathogen

***Bipolaris oryzae* [syn. *Helminthosporium oryzae* (Teleomorph: *Cochliobolus miyabeanus*)]**

Credit: Shrinkhala Manandhar

Conidia of *Bipolaris oryzae*

Identification

Infected seedlings have small, circular, yellow brown or brown lesions that may girdle the coleoptile and distort the primary and secondary leaves, causing seedling blight.

At tillering stage, lesions can be observed on the leaves. They are initially small, circular, and dark brown to purple-brown. Fully developed lesions are circular to oval with a light brown to gray center, surrounded by a reddish-brown margin.

Credit: Hira Kaji Manandhar

Initial to fully grown brown spots (left to right) on rice leaves

Credit: Hira Kaji Manandhar

Rice field heavily infected by brown spot (left) and rice panicles with the growth of *Bipolaris oryzae* covering whole grains (right)

Lesions on leaf sheaths are similar to those on the leaves. Infected glumes and panicle branches have dark-brown to black oval spots or discolouration on the entire surface. Spikelets can also be infected. Infection of florets leads to incomplete or disrupted grain filling and a reduction in grain quality (see also Grain discolouration).

Scoring (at growth stage 3-6)

Scale	Infected leaf area
0	No incidence
1	Less than 1%

Scale	Infected leaf area
2	1-3%
3	4-5%
4	6-10%
5	11-15%
6	16-25%
7	26-50%
8	51-75%
9	76-100%

(Source: IRRI, 2002)

Disease

Sheath blight (शीथ व्लाइट / पाते फेद डढुवा)

Sheath blight is a major fungal disease next to rice blast and brown spot in Nepal. The incidence and severity of the disease is increasing in intensified and hybrid rice production systems. The pathogen is soil borne and survives in crop debris.

Pathogen

Rhizoctonia solani (*Teleomorph: *Thanatephorus cucumeris)

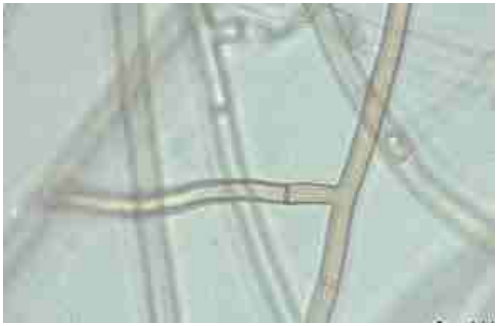


Photo: Gerald Holmes
Source: https://sites.google.com/site/plantevolutionarydiversity/deuteromycota

Hyphae of *Rhizoctonia solani*

Identification

Symptoms are usually observed from tillering to milk stage in the rice crop. Symptoms include oval or ellipsoidal greenish-gray lesions, usually 1-3 cm long, on the leaf sheath, initially just above the soil or water level in conventionally flooded rice fields.

Under favourable conditions, initial lesions multiply and expand to the upper part of the sheaths and leaves, and then spread to neighboring tillers of different hills (transplanted rice) or plants (direct-seeded rice). Lesions on the leaves usually have irregular lesions, often with gray-white centers and brown margins as they grow older. The infection may even reach to panicle causing grain blight as seen in picture below.

Credit: Hira Kaji Manandhar

Source: www.knowledgebank.irri.org

Photo: Nigel Cattlin, Source: www.gettyimages.com

Sheath blight on lower rice part (left); leaf (center); and kernel (right)

Scoring (at growth stage 3-6)

Scale	Relative lesion height
0	No infection observed
1	Lesions limited to lower 20% of the plant height
3	20-30%
5	31-45%
7	46-65%
9	More than 65%

(Source: IRRI, 2002)

Disease

Sheath rot (शीथ रट् / पाते फेद कुहिने)

Sheath rot, a commonly occurring fungal disease, is a major disease of rice. Severe infection during or before emergence of the panicle may cause heavy reductions in grain yield. Infected seeds and mycelium of the fungus carried in the rice crop residue play an important role as sources of inoculum for primary infection.

Pathogen

***Sarocladium oryzae* (syn. *Acrocylindrium oryzae*)**

Credit: Gyanu Manandhar

Conidia of *Sarocladium oryzae*

Identification

The typical sheath rot lesion starts at the uppermost leaf sheath enclosing young panicles. It appears oblong or as an irregular spot with dark reddish, brown margins, a gray center or brownish-gray throughout.

Usually several spots are observed and these spots enlarge and coalesce or grow together and can cover most of the leaf sheath. Panicles remain within the sheath or may partially emerge. Panicles emerged from affected plants often have discoloured and blighted grains, which may be partially filled or chaffy.

Credit: Hira Kaji Manandhar

Sheath rot of rice

Scoring (at growth stage 7-9)

Scale	Severely affected tiller
0	No incidence
1	Less than 1%
3	1-5%
5	6-25%
7	26-50%
9	51-100%

(Source: IRRI, 2002)

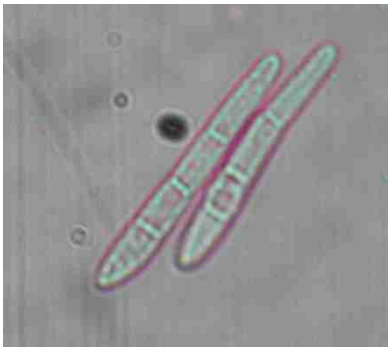
Disease

Narrow brown spot (न्यारो ब्राउन लिफ स्पट / सानो खैरो थोप्ले)

Narrow brown spot is a commonly occurring but minor fungal disease. The disease appears mostly at maturity stage. Its prevalence is more common in cooler parts of the high hills and also in dry conditions of the terai plain. The pathogen is seed borne.

Pathogen

***Cercospora oryzae* (Teleomorph: *Sphaerulina oryzina*)**



Credit: Gyanu Manandhar

Conidia of *Cercospora oryzae*

Identification

Typical lesions on leaves and upper leaf sheath are light- to dark-brown, linear, and progress parallel to the vein. They are usually 2–10 mm long and 1–1.5 mm wide.

Lesions on the leaves of highly susceptible varieties may enlarge and combine together, forming brown linear necrotic regions.

The disease also causes discolouration on the leaf sheath, referred to as "net blotch" because of the net like pattern of brown and light brown or yellow areas.


Credit: Hira Kaji Manandhar


Source: www.knowledgebank.irri.org


Credit: Anju Pandey


Credit: Gyanu Manandhar

Young lesions (left), longer lesions (middle left), shorter lesions and sporulating narrow brown spots (right) on rice leaves

Scoring (at growth stage 3-6)

Scale	Infected leaf area
0	No incidence
1	Less than 1%
2	1-3%
3	4-5%
4	6-10%
5	11-15%
6	16-25%
7	26-50%
8	51-75%
9	76-100%

(Source: IRRI, 2002)

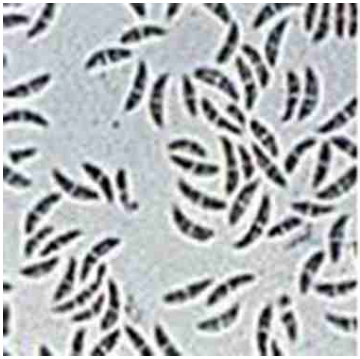
Disease

Leaf scald (लिफ स्काल्ड / पात डढुवा)

Leaf scald is a commonly occurring fungal disease. The disease generally appears at maturity stage of the crop. It is seed borne and the pathogen may survive in crop debris.

Pathogen

Microdochium oryzae* (syn. *Gerlachia oryzae, Rhynchosporium oryzae)



Source: http://agritech.tnau.ac.in/expert_system/paddy/cpdisleafscald.html

Conidia of *Microdochium oryzae*

Identification

The symptoms appear as zonate lesions of alternating light tan and dark brown starting from leaf tips or edges. The lesions are oblong with light brown halos in mature leaves.

Source: http://www.rkmp.co.in/content/symptoms-of-rice-leaf-scald-disease

Credit: Anju Pandey

Source: http://www.knowledgebank.irri.org

Leaf scald symptom on leaf tips (left and center) and edges (right) of rice

Individual lesions are 1–5 cm long and 0.5–1 cm wide or may almost cover the entire leaf. The lesions enlarge and coalesce, which results in blighting of a large part of the leaf blade. The affected areas dry out giving the leaf a scalded appearance.

Leaf scald, especially at later stages, can be confused with bacterial leaf blight. To confirm scald, visually examine the leaf for scalded appearance. Immerse cut leaves in clear water for 5–10 minutes, if no ooze comes out, then it is leaf scald.

Scoring (at growth stage 5-8)

Scale	Affected leaf area
0	No incidence
1	Less than 1% (apical lesions)
3	1-5% (apical lesions)
5	6-25% (apical and some marginal lesions)
7	26-50% (apical and marginal lesions)
9	51-100% (apical and marginal lesions)

(Source: IRRI, 2002)

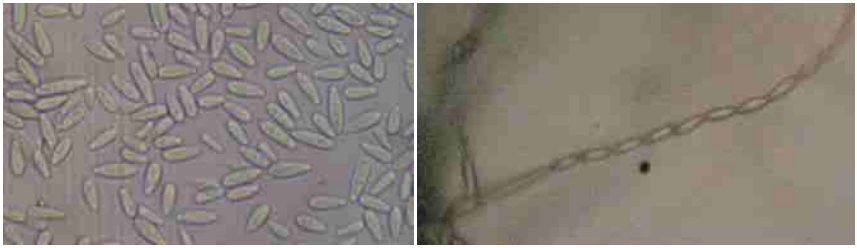
Disease

Foot rot (फुट रट् / फेद कुहिने)

Bakanae/foot rot disease is a commonly occurring fungal disease, but its incidence and severity is high in some rice varieties like Khumal-4. The disease is primarily seed borne and seed transmitted, though the fungus may live in soil and crop debris.

Pathogen

***Fusarium proliferatum* (earlier known by *Fusarium moniliforme*)**



Credit: Gyanu Manandhar

Microconidia (left) and conidia in a chain (right) of *Fusarium proliferatum*

Identification

The characteristic symptom includes pale and taller plants, which may appear under both seed bed and transplanted conditions. Later, rotting of lower stems above the soil occurs and the plants die.

Credit: Hira Kaji Manandhar

Pale and taller rice plants and foot rot in rice field

Scoring (at growth stage 3-6)

Scale	Infected plants
0	No disease observed
1	Less than 1%
5	1-25%
9	26-100%

(Source: IRRI, 1996)

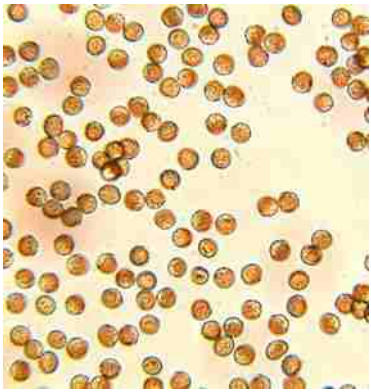
Disease

False smut (फल्स स्मट / कालोपोके)

False smut is a commonly occurring minor fungal disease, but it has become severe in isolated fields with certain varieties and hybrids. The initial stage of the disease occurs at the early flowering stage of rice crop, when the ovary is destroyed. The second stage of infection occurs when the spikelet nearly reaches maturity.

Pathogen

Ustilaginoidea virens



Source: http://agridr.in/expert_system/paddy/cpdisfals egraindis.html

Teliospores (chlamydospores) of *Ustilaginoidea virens*

Identification

Plants infected with false smut have individual rice grains transformed into a mass of spore balls (sori). These spore balls are initially orange, and then turn greenish-black when mature. In most cases, not all spikelets of a panicle are affected, but spikelets neighboring smut balls are often unfilled.

Credit: Hira Kaji Manandhar

Spore balls of false smut of rice, initially orange (left) and later turning greenish-black (right)

Scoring (at growth stage 9)

Scale	Infected florets
0	No incidence
1	Less than 1%
3	1-5%
5	6-25%
7	26-50%
9	51-100%

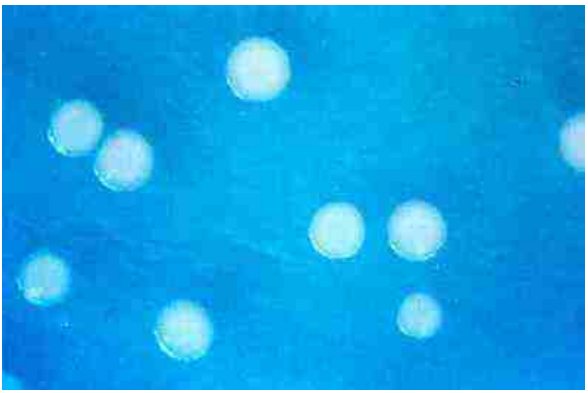
(Source: IRRI, 2002)

Disease

Bacterial sheath brown rot (व्याक्टेरियल शीथ ब्राउन रट्)

Bacterial sheath brown rot is a cold-associated disease that occurs in mountains and shady areas. Panicle fails to exert. It is seed borne and seed transmitted disease. Chhomrong, Machhapuchhre-3 and Lumle-2 are reported to be field resistant.

Pathogen
Pseudomonas fuscovaginae



Source: www.knowledgebank.irri.org

Fluorescent colonies of *Pseudomonas fuscovaginae*

Identification

Symptoms of discolouration typically occur on the flag leaf sheath at booting stage and on the panicle. Disease symptoms may be confused with fungal sheath rot caused by *Sarocladium oryzae*. It can be distinguished by the oozing test under a microscope, which occurs when bacteria ooze out from the cut part of the plant tissue.

When plants are mature, oblong to irregularly shaped dark green, water-soaked lesions occur, which later turn gray-brown or brown, and may be surrounded by an effuse dark brown margin. The sheath may also exhibit general water-soaking and necrosis without definable margins.

With severe infections, the entire leaf sheath may become necrotic, dry out, and the panicle withers. Glumes emerging from infected plants exhibit water-soaked lesions that turn light brown. Grains of infected panicles are discoloured, deformed, or empty.

Credit: Hira Kaji Manandhar

Source: www.knowledgebank.irri.org

Bacterial brown sheath rot of rice at early (left) and late (center) stages with discoloured grains (right)

Scoring (at growth stage 7-9)

Scale	Severely affected tiller
0	No incidence
1	Less than 1%
3	1-5%
5	6-25%
7	26-50%
9	51-100%

(Source: IRRI, 2002)

Disease

Grain discolouration (ग्रेन डिस्कलरेसन / दागी दाना)

Grain discolouration is caused by one or more fungal and bacterial pathogens. The disease is common in cool and humid climate.

Pathogen

Species of *Sarocladium, Bipolaris, Alternaria, Microdochium, Fusarium, Phoma, Curvularia, Psuedomonas,* etc

Identification

Darkening of glumes of spikelets, brown to black colour including rotten glumes caused by one or more pathogens. Intensity ranges from sporadic discolouration to discolouration of the whole glume.

Credit: Hira Kaji Manandhar

Grain discolouration of rice with disease spots

Scoring (at growth stage 8-9)

Scale	Grains with severely discoloured glumes
0	No incidence
1	Less than 1%
3	1-5%
5	6-25%
7	26-50%
9	51-100%

(Source: IRRI, 2002)

References

IRRI. 2002. Standard evaluation system for rice. International Rice Research Institute. Manila Phillipines.

IRRI. 2015. Knowledge Bank – Diseases. http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/diseases.

Manandhar, H.K. 1987. Rice diseases in Nepal. Plant Pathology Division, Department of Agriculture, Nepal and Agriculture Research and Production Project, Winrock International.

Ou, S.H. 1985. Rice diseases. Second edition. Commonwealth Mycological Institute, Kew, UK.

Sthapit, B.R., Pradhanang, P.M. and Witcombe, J.R. 1995. Inheritance and selection of field resistance to sheath brown rot disease in rice. Plant Disease 79:1140-1144.

Webster, R.K. and Gunnell, P.S. eds. 1992. Compendium of rice diseases. APS Press. the American Phytopathological Society, USA.

मानन्धर, हीराकाजी । २०४७ । धानबालीमा लाग्ने रोगहरु र तिनका रोकथाम । बाली संरक्षण अनुसन्धान तथा सेवा केन्द्र, काठमाडौं ।

Tips for Rating Disease in Small Grains

by Nathan Kleczewski

On farm trials are useful tools used by agricultural professionals such as extension specialists, extension agents, consultants, and growers. When conducted and assessed properly, on farm trials can greatly increase grower profitability. The objective of this note is to share basic techniques of rating on farm trials for foliar diseases of small grains.

Important Terms

Severity - often the percent of disease on a leaf or plant.

Incidence - the number of plants with disease out of a given number of plants.
Example: If 10 plants out of 20 have grey leaf spot and the severity ratings are 5,5,5,5,5,5,5,5,5,5,0,0,0,0,0,0,0,0,0,0, and 0 %, then the severity for the plot is the average of the percentage of disease = (Sum of severity ratings=50)/(number of plants rated=20) = 2.5%. The disease incidence for the plot is 10/20 or 50%.

Random - a decision made without bias or method. You should not select only healthy or diseased plants to rate. Instead, several sites within a plot or strip should be selected haphazardly for rating. At each site close your eyes, reach out, and touch a plant. Rate only the plant you touched while your eyes were closed.

Methods

There are many methods and keys that can be used to assess disease on leaves or plants. None of these methods are necessarily more correct than another, and all have strengths and weaknesses. The one thing that is important is to utilize the same rating scale within a field or test. A publication often used to assess common diseases on small grains, corn, and soybean is Clive James' 1971 book entitled, A Manual of Assessment Keys for Plant Diseases published by APS press.

In general, you should rate disease severity and incidence on 20-50 plants per plot/strip. The number of plants you sample depends on the size of the experiment and plot as well as the length of time required to rate the experiment. Increasing the number of plants you sample will increase the accuracy and reliability of the data, whereas sampling fewer plants will make rating faster but will likely result in highly variable data. Excessive variability can make assessing test effects nearly impossible.

Always rate plants located away from the edges of a plot or strip, tire tracks, and field edges. Plants in these locations are often not representative of the plot/strip at they experience different environments (e.g. wind, moisture, temperature) than those within plots/strips.

Rating Tips

It is essential that ratings are made while the diseases are easy to identify and during a period that they are likely to influence yield. The following stages are considered standard for rating diseases on many field crops. The exceptions are early season diseases impacting emergence (e.g. *Rhizoctonia, Phytophthora*), ear diseases, and post-harvest diseases.

Small grains

At the early dough stage, rate the flag leaf (F) and the next leaf down (F-1) on a plant. Record F and F-1 ratings separately. Rate one head per plant.

Bean

At the full seed stage (R6) rate the upper 1/3 to 1/4 of the canopy. Rate leaves or pods depending on the disease. Randomly select and rate one leaf or pod per plant. Use the main stem if rating stem diseases such as charcoal rot or brown stem rot.

Other Tips

If you are testing a treatment for disease control, you MUST rate disease. Any conclusions about the effectiveness of a treatment or impacts on yield are invalid without disease data to support these claims. Claiming that a treatment for disease control impacts yield without assessing disease levels is just as invalid.

Test yourself against a colleague or individual experienced in rating plant diseases on the crop of interest. How close are your ratings? The more you rate, the more consistent your ratings will be.

There are several items you should carry with you when rating a test for disease. The most important is a notebook or binder for recording data. Always note the date, crop growth stage, person/people rating, and other information that may influence the results such as recent weather, variety, GPS record and management practices.

Rating on farm trials can be time consuming. Take a 3-5 minute break approximately every 30 minutes. You will notice an increase in data entry errors when fatigue sets in.

Many times it is better to rate experiments in pairs. Work together within in a strip or plot, but do not work on separate plots simultaneously as this can bias results. Make ratings blindly to avoid any potential rating bias.

Reference

James, W.C. 1971. A manual of assessment keys for plant diseases. Canada Department of Agriculture, Publication No. 1458. The American Phytopathological Society, USA.

Kleczewski, N. 2014. Tips for rating disease in small grains, corn, and soybean. (Available at: http://extension.udel.edu/fieldcropdisease/2014/01/03/tips-for-rating-disease-in-small-grains-corn-and-soybean/)

Appendices

Appendix 1.

Growth Stages of Rice

Code	Stage
1	Germination
2	Seedling
3	Tillering
4	Stem elongation
5	Booting
6	Heading
7	Milk stage
8	Dough stage
9	Mature grain

Source: IRRI. 2002. Standard evaluation system for rice. International Rice Research Institute. Manila Phillipines.

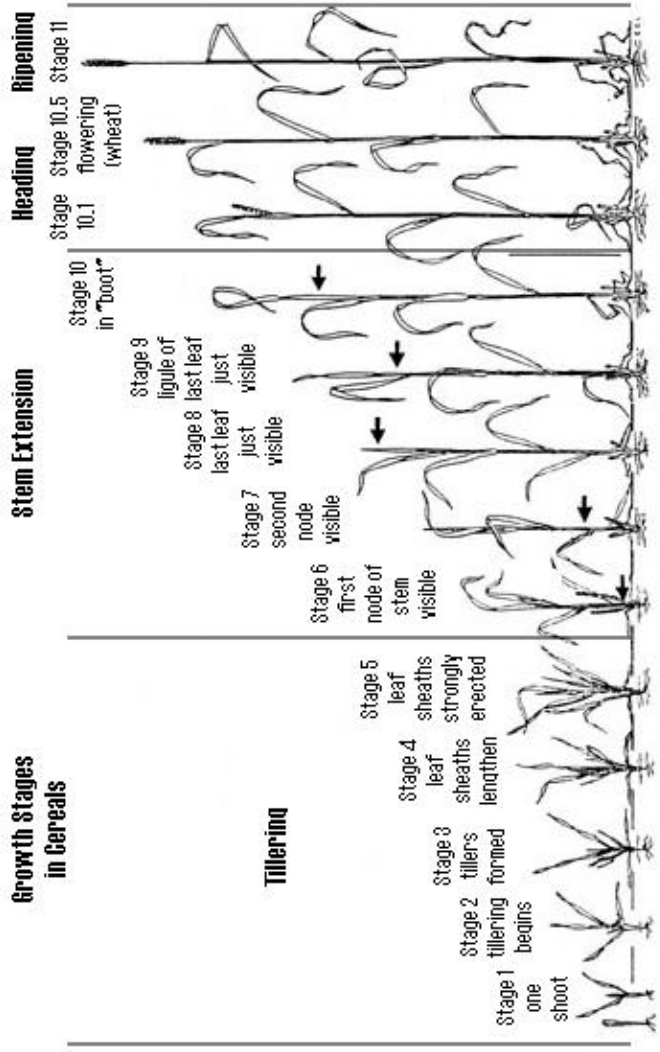
Appendix 2.

Growth Stages of Barley

Code	Stage
1	One shoot
2	Beginning of tillering
3	Tiller formed leaves often twisted spirally
4	Beginning of erection of the pseudo stem leaf sheath beginning to lengthen
5	Pseudo stem (formed by sheath of leaves) strongly erected
6	First Node of stem visible at base of shoot
7	Second node of stem formed next to last leaf just visible
8	Last leaf visible but still rolled up spike beginning to swell
9	Ligule of last leaf just visible
10	Sheath of last leaf completely grown out spike swollen but not visible
10.1	First spike just visible (awn just showing in barley, refer Figure 10.1)
10.2	Quarter of the heading process completed
10.3	Half of heading process completed
10.4	Three quarter of the heading process completed
10.5	All spike out of sheath
10.5.1	Beginning of flowering
10.5.2	Flowering complete to top of spike
10.5.3	Flowering over at base of spike
10.5.4	Flowering over kernel watery ripe
11.1	Milky ripe
11.2	Milky ripe content of kernel soft but dry

Code	Stage
11.3	Kernel hard difficult to divide thumb–nail
11.4	Ripe for cutting straw dead

Source: Large, E.C. 1954. Growth stages in cereals illustration of the Feekes scale. Plant Pathology 3:128-129.



According to Large (1954) cereals develop as follow Feekes Growth Stages

Stage

Tillering

1 One shoot (number of leaves can be added) = "brairding"
2 Beginning of tillering
3 Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be "creeping" or prostrate
4 Beginning of the erection of the pseudo-stem, leaf sheaths beginning to lengthen
5 Pseudo-stem (formed by sheaths of leaves) strongly erected

Stem Extension

6 First node of stem visible at base of shoot
7 Second node of stem formed, next-to-last leaf just visible
8 Last leaf visible, but still rolled up, ear beginning to swell
9 Ligule of last leaf just visible
10 Sheath of last leaf completely grown out, ear swollen but not yet visible

Heading

10.1 First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats)
10.2 Quarter of heading process completed
10.3 Half of heading process completed
10.4 Three-quarters of heading process completed
10.5 All ears out of sheath

Flowering (Wheat)

10.5.1 Beginning of flowering (wheat)
10.5.2 Flowering complete to top of ear
10.5.3 Flowering over at base of ear
10.5.4 Flowering over, kernel watery ripe

Ripening

11.1 Milky ripe
11.2 Mealy ripe, contents of kernel soft but dry
11.3 Kernel hard (difficult to divide by thumb-nail)
11.4 Ripe for cutting. Straw dead

Source: Large, E.C. 1954. Growth stages in cereals. Plant Pathology 3:128-129.

Appendix 3.

Development Stages of Common Bean Plant

Stage[a]	Description[b]
V0	Germination: Water absorption by the seed, emergence of the radical, and transformation into the primary root.
V1	Emergence: Cotyledons appear at soil level and begin to separate. The epicotyls initiates its development.
V2	Primary leaves: Totally opened primary leaves.
V3	First trifoliate leaf: The first trifoliate leaf opens and the second trifoliate leaf appears.
V4	Third trifoliate leaf: The third trifoliate leaf opens and the buds on the lower nodes produce branches.
R5	Preflowering: The flower bud or the first raceme appears. Flower buds in determinate varieties are formed on the last stem or branch node. In indeterminate varieties racemes are first observed on the lower nodes.
R6	Flowering: The first flower opens.
R7	Pod formation: The first pod appears being more than 2.5 cm long.
R8	Pod filling: The first pod begin to fill (seed growth). At the end of the stage the seeds lose their green colour and begin to show varietal characteristics. Defoliation initiates.
R9	Physiological maturity: Pods lose their pigmentation and begin to dry. Seeds develop their typical varietal colour.

[a.] V = vegetative; R = reproductive

[b.] When evaluating populations, each stage begins when 50% of the plants show the conditions that correspond to the description.

Source: Fernández, F. P. Gepts, and López, M. 1986. Etapas de desarrollo de la planta de frijol común (*Phaseolus vulgaris* L.), CIAT, Cali, Colombia.

Appendix 4.

Double digit scoring

The double digit scale (00 to 99), developed by the modification of Saari & Prescott's Scale, measures overall foliar infection on the whole plant on the basis of two digit, where;

1. The first digit (D1) indicates disease progress in canopy height from the ground level,
2. The second digit (D2) refers to severity of the disease based on diseased leaf area (Nagarajan, 1998).

Thus, D1 represents vertical extent and D2 represents horizontal extent. Both D1 and D2 gradations were expressed in 1-9 scale (Mujeeb-Kaji et.al, 1996).

Percentage disease severity can be calculated by the following formula:

Disease Severity (%) = $(D_1/9) \times (D_2/9) \times 100$

Where,
D_1 = first digit / height of infection
D_2 = second digit / severity of infection

Scale for height of infection	Scale for Severity of infection
1 = lowest leaf	1 = 10% coverage
2 = second leaf from base	2 = 20% coverage
3-4 = second leaf upto below middle of plant	3 = 30% coverage
5 = upto middle of plant	4 = 40% coverage
6-8 = from center of plant to below of the flag leaf	5 = 50% coverage
9 = upto flag leaf	6 = 60% coverage
	7 = 70% coverage
	8 = 80% coverage
	9 = more than 90% coverage

Scale	Reaction	Host response
1	00 score	Immune
2	01 – 14 score; lesions absent or small without chlorosis	Resistant
3	15 – 35 score; lesions small but with some chlorosis	Moderately resistant
4	36 – 55 score; lesions large with extensive chlorosis but little or no coalescence	Moderately susceptible
5	56 – 79 score; lesions large and coalescence with chlorosis	Susceptible
6	> 79 score; lesions large and extensive coalescence with severe chlorosis	Highly susceptible

(Source: Singh et al., 2014)

Reference

Singh, S., Singh, H., Sharma, A., Meeta, M., Singh, B., Joshi, N., Grover, P., Al-Yassin, A. and Kumar, S. 2014. Inheritance of spot blotch resistance in barley (*Hordeum vulgare L.*). Canadian Journal of Plant Science, 94:17 doi:10.4141/CJPS2013-153

Nagarajan, S. 1998. DWR leaf blight screening nursery. Progress Report, 1998. CP Vol. V. 44 pp

Mujeeb-Kaji, A., Villareal, R.L., Gilchrist, L.I. and Rajaram, S. 1996. Registration of five wheat germplasm lines resistant to *Helminthosporium* leaf blight. Crop Science 36:216-217.

Appendix 5.

Household survey questionnaire

Household No. (001 to 060) _____
(example of a final code: D06001 = Dolakha- Finger millet- first household surveyed)

Crop genetic diversity to reduce pests and diseases on-farm
HH Individual Interview Form + Farmer Field Observations

Crop: Naked Barley (01) / Rice (02) / Common Bean (03) / Buckwheat (04) / Amaranths (05) / Finger Millet (06)/ Foxtail Millet (07)/ Proso Millet (08)

Site Name: Dolakha (D)/ Humla (H)/ Jumla (J) / Lamjung (L)

PART I: Individual Interview

(NOTE: To be taken during first visit at the farmer's home and with 30 head male and 30 head female farmers – regardless of head of household)

Household Head Name: _____

Farmer Name: _____

Sex: Male / Female

Village Name: _____

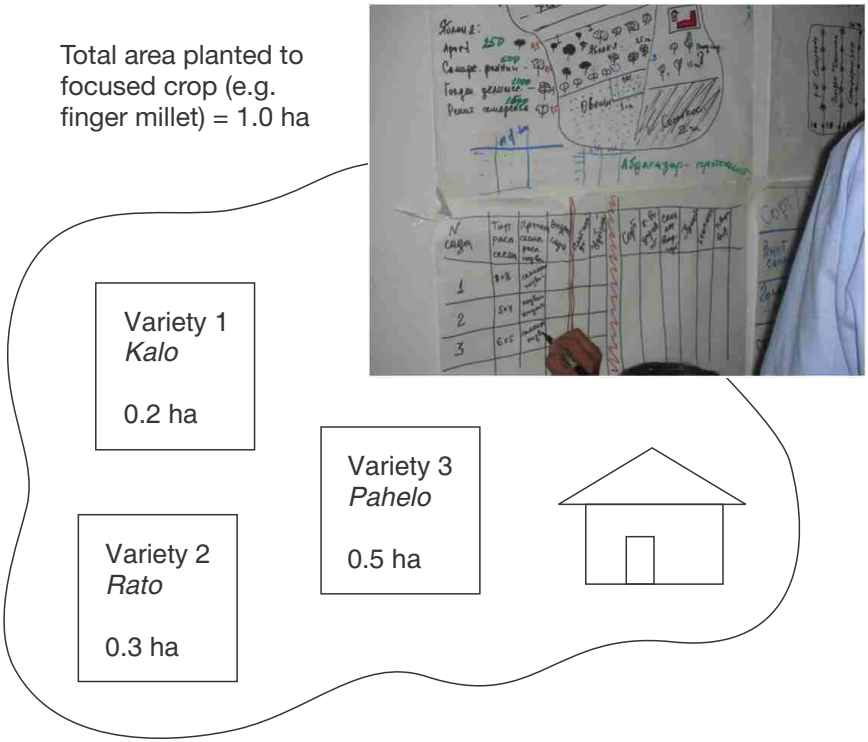
Interviewer asks: "We would like to understand the varieties you cultivate of focused crop X and its distribution among and within plots"

The interviewer then asks the farmer to draw a farm map showing: a) boundaries and area of his/her land, and marking this according to how he/she divides the farm into plots (write the plot name or label if applicable).

The interviewer then asks the farmer to give: a) <u>total area</u> of his/her farm (write this on the top part of the map), and b) <u>area</u> of

each plot (write inside each box representing the plot). Then the interviewer asks the farmer to identify for each plot/field the crop/s planted for the current season - labelled by name, symbol and/or divided into sub-plots. Then for each target crop of the project grown at this site, the interviewer ask the farmer what varieties of each target crop are grown for each plot/sub-plot, and the interviewer + farmer labels the each plot with the names of the varieties.

A. Farm mapping showing spatial distribution of varieties among and within plots (example map shown below)



Based on this farm map, the interviewer has now determined where the Focus Crops (X) are grown by the farmer and the varieties of these crops.

Note: Also record the GPS readings on each of the plots drawn on the Map drawn by the farmer in the Individual Survey section 1. Make sure that the home garden and any varieties in the home garden are also included, or if any special plots are used for seed multiplication are included on the MAP.

Plot No.	Total Plot Area (Unit)	Variety 1	Variety 2	Variety 3	Variety 4	Variety 5	GPS Reading		
							Latitude	Longitude	Altitude
1									
2									
3									
4									
5									
Sum									

B. Varieties currently grown and grown in the last ten years + farmers evaluation of traits of his/her variety

Interviewer says: "Now let's talk about crop X (specific Focus Crop). Besides the varieties you grow this year which you put on the map and I have listed below, what other varieties have you grown in the last 10 years? "

Note to interviewer: Transfer the list of varieties identified in the map you did with the farmer to the table below. Together with the area grown to each variety from the map above. Do not again ask the farmer the list of varieties he or she is growing now as you already have them from the map you drew earlier. The list of varieties below should include all varieties, both modern and traditional, but the focus of the rest of the information is on the potential of traditional/local varieties and diversity-rich practices.

Variety	Area planted to each variety	Home Garden =1; Field = 2	How many years have you grown them?	How often do you change seeds for this variety?	Farmer's evaluation of traits								
					Ex. Drought resistant	Ex. Taste	Good storage	High yield	Disease resistant	Criteria 6	Criteria 7		
Varieties Grown This Year (list from the information in the map)													
*	*	*											
Other Varieties Not Currently in the Field, but Grown in the Last 10 years†													

* Note here the interviewer writes in the names and areas from the map drawn above

† To probe for other varieties previously grown, refer to other varieties grown in the community as mentioned in earlier PRA, FGD and Baseline Survey

If the farmers changes seeds of a given variety, the interviewer then asks "For what reasons did you change seeds for variety X?" (Use list of reasons from FGD/PRA. And check the appropriate reason listed by the farmer)

Reason 1 _____
Reason 2 _____
Reason x _____

If the farmers changes varieties often, the interviewer then asks "For what reasons did do you rotate among varieties?" (Use list of reasons from FGD/PRA. And check the appropriate reason listed by the farmer)

Reason 1 _____
Reason 2 _____
Reason x _____

PART II: On-farm Disease Scoring

A. Overall Guidelines for Farmer Field Disease and Pest Evaluation

(NOTE: To be taken during second visit at the farmer's field during scoring stage of focused crop)

The following describes the steps involved in conducting disease and pest evaluations for on-farm surveys that are attached to the household survey of all 60 farms interviewed per site. The purpose of these procedures is to obtain objective observations of the severity of project diseases and pests for each variety the farmer is growing by collecting the observations in such a way that they are representative of each farm.

For each variety the farmer grows give a score for each project target disease or pest. The score for each variety will be the average of 30 observations and each score should be for one or more individual plants

Step 1. Take the map of the farmer's field you drew with the farmer during the HH survey for the location of each plot and the varieties grown in each plot.

Step 2. Go to each plot where the target crop is planted and note differences in shape of the plot and changes in elevation across the plot. Draw a larger picture of each plot which you will use to mark disease or pest severity ratings.

If the variety is growing in several plots, then rate the variety is as many distinct plots as possible. If all plots cannot be rated, then rate as many as possible and select plots that are farther apart or at different elevations on the same farm over plots that are closer to each other. The purpose is to allow you to have a total of 10 spots or 30 observations per variety that cover the variability of the different plots planted to the same variety.

Step 3. Pick a starting point for each plot and walk in a zig-zag path from one end of the plot to the other covering the whole planting of that variety, crossing different rows, avoiding the edge, and from high to low elevation, as shown in the Diagram 1 below. If walking zig-zag through the field will cause too much damage to the crop walk into the plot at different points along the plot as shown in Diagram 2.

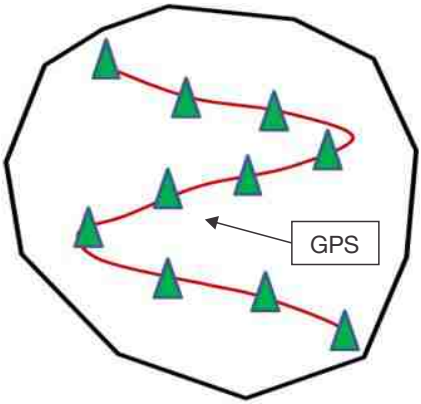


Diagram 1

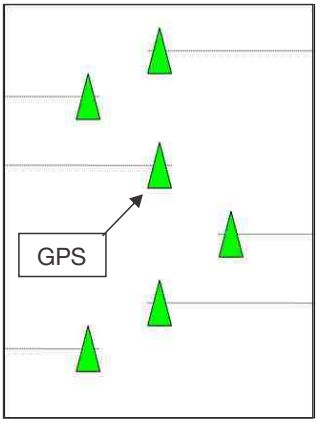
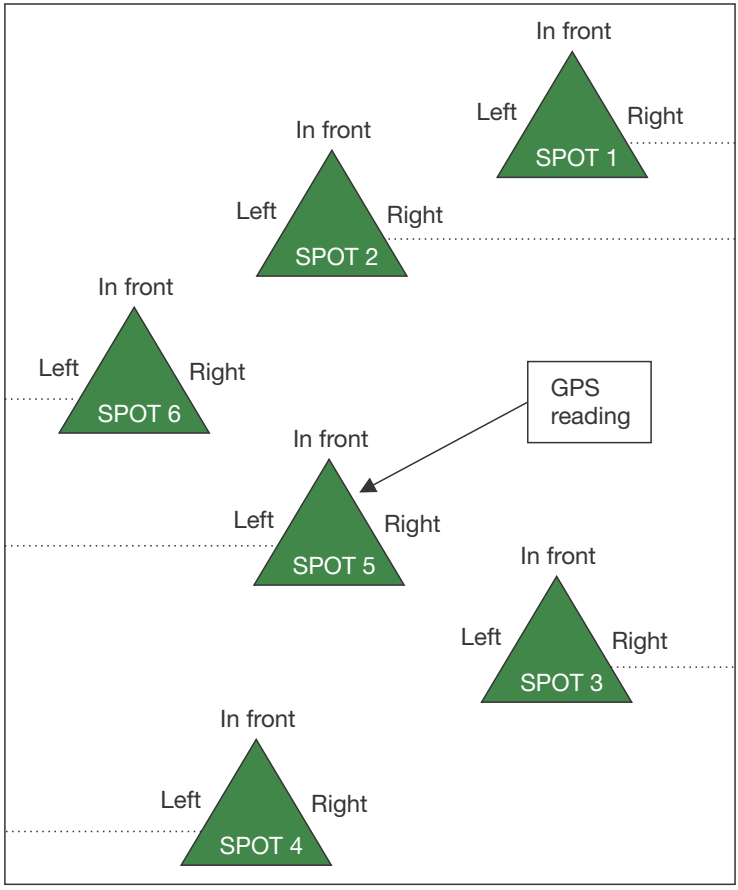


Diagram 2

Step 4. Stop at 10 spots along this path (or if the variety is grown in three plots, you may make 3 stops in one plot, 3 stops in another plot, and 4 stops in the third plot). Larger plots will have more steps between each spot and smaller plots will have fewer steps.

Step 5. At each stopping spot make three observations: one to the left, one to the right, and one straight-ahead. Write these observations on your drawing of the plot. Rate one or more plants in each of these areas using the rating scale provided for the target disease or pest. Take a GPS reading when you are in the middle of each plot.



Note: If varieties are grown in a mixture, then each mixture should have 30 observations.

- Use the map you drew with the farmer to locate plots with mixtures.
- The map should have names of the varieties in the mixture; if not, add them to the map.
- Check also with the farmer if the proportions of the different varieties they gave you earlier are correct. You might see differences in a plot that a farmer has said has only one variety (or drawn only one variety on the earlier map), ask the farmer whether the different height of plants or different looking plants within the plot are different varieties. If so ask the farmer to tell you what proportion of the seeds are of each variety, and go back and modify the original plot map in the survey.
- If possible, record the disease or pest rating separately for each variety in the mixture for a total of 30 observations. For example, disease score for short + disease score for tall = 30 total, but you might have 10 of the short and 20 of tall or 15 of short and 15 of tall.

EXAMPLE: Ratings for Disease severity and incidence

Variety Name _____

Example: Leaf Blast in Rice

Disease Severity (Scale 1-4) *Check Annex 3 for disease scoring details*

Percent of Disease Incidence (0 - 100%) *Check Annex 3 for disease scoring details*

Observation	Spot	Disease Incidence Scoring Crop: Rice; Variety: Lumle-2			
		Leaf Blast		DI calculation (Incidence x Severity) / highest severity	DI
		% incidence in population observed (0-100%)	Severity (1-4)		
01	Spot 1 - right	60	2	= (60*2)/4	30
02	Spot 1 - left	30	1	= (30*1)/4	7.5
03	Spot 1 - front	0	0	= (0*0)/4	0
04	Spot 2 - right	10	1	= (10*1)/4	2.5
05	Spot 2 - left	20	3	= (20*3)/4	15
06	Spot 2 - front	20	3	= (20*3)/4	15
				Mean (Lumle-2)	11.7

Example of WDI (Weighted Damage Index) Calculation

Variety	Proportion of Area	DI	WDI
Lumle -2	0.3	11.7	0.3*11.7 = 3.51
Chhomrong	0.7	50.2	0.7*50.2 = 35.14
			3.51 + 35.14 = 38.65

Code HOUSEHOLD No. _____

Surveyor name_____

Crop _____

Variety name _____

GPS reading (1 at center of each plot) _____

Observation	Spot	Location	Disease 1		DI calculation (Incidence x Severity) / highest severity	DI (Damage Index)	GPS reading
			Incidence (%)	Severity (1-4)			
01	1	Right					
02	1	Left					
03	1	Front					
04	2	Right					
05	2	Left					
06	2	Front					
07	3	Right					
08	3	Left					
09	3	Front					
010	4	Right					
011	4	Left					
012	4	Front					
013	5	Right					
014	5	Left					
015	5	Front					
016	6	Right					
017	6	Left					
018	6	Front					
019	7	Right					
020	7	Left					
021	7	Front					
022	8	Right					
023	8	Left					
024	8	Front					
025	9	Right					
026	9	Left					
027	9	Front					
028	10	Right					
029	10	Left					
030	10	Front					

PART III: Use of product and control inputs

Use of product and control inputs (pesticides and chemical fertilizers) and other methods for controlling pests and diseases

(NOTE: To be taken during end of season or after harvest visit at the farmer's home)

Note to Interviewer: To determine the use of pesticides and chemical fertilizers ask farmer to estimate amounts (containers; bottles – ask the farmer to show you the container to get an idea of size) of pesticide/chemical fertilizer (if any) used, and number of times the pesticide, was put in each plot this year. Ask the farmer to tell you the amount of dilution with water (e.g. number of packages per container).

NOTE: Prior to the interview talk with the village leaders/nearby agrovets to have knowledge of the control inputs available, containers (size) and dilution farmers use so that you only need to know number of containers the farmer applied.

Mark use of pesticide in blue and use of fertilizer in black on the copy of the map produced with Question 1. (This assumes the interview is done towards end of season, to be able to estimate total amounts applied for that season).

Do you use any of these methods that you have talked about for controlling pest and diseases	Mark ✓
Plant improved varieties	
Crop rotation (species)	
Plant crop mixtures, two different crops in the same field	
Trapping insects	
Field sanitation (remove disease plants) from the field	
Fertilize the soil with chemical fertilizers	
Fertilize the soil with NON chemical fertilizers	

Do you use any of these methods that you have talked about for controlling pest and diseases	Mark ✓
Fertilize the area of the field where you will collect the seeds	
Other soil management practices to compensate for loss of nutrients to the plant from pest and diseases	
Weeding out other plants (not the target crop but other species)	
Decrease spacing density	
Other	
Other	
Other	

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ISBN 978-92-9255-052-3