

**Evaluation of barnyard millet germplasm for morphometric
characterization and screening against important endemic
diseases in mid-hills of Uttarakhand**

Thesis

SUBMITTED TO THE



**Department of Seed Science and Technology
College of Forestry, Ranichauri
VCSG Uttarakhand University of Horticulture and Forestry,
Bharsar-246123, Pauri Garhwal-246123, Uttarakhand, India**

By

**NEELAM PAVAN KUMAR
Id. No. UUHF/21321**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

**MASTER OF SCIENCE IN AGRICULTURE
(SEED SCIENCE AND TECHNOLOGY)
2023**



Dr. Laxmi Rawat
Officer In-Charge
Plant Pathology Division

**V.C.S.G. UTTARAKHAND UNIVERSITY OF
HORTICULTURE & FORESTRY, BHARSAR**
Plant Pathology Division, College of Forestry
Ranichauri (249 199), Tehri Garhwal, Uttarakhand
Mob. +91-7983822911, Ph. +91-1376-252657 (0)
E-mail: pathologyranichauri1401@gmail.com

CERTIFICATE-I

—
This is to certify that the thesis entitled **“Evaluation of barnyard millet germplasm for morphometric characterization and screening against important endemic diseases in mid-hills of Uttarakhand”** submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in Agriculture in the discipline of **Seed Science and Technology** of VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India is a bonafide research work carried out by **Mr. Neelam Pavan Kumar, Id No. UUHF/21321** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

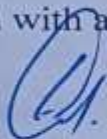
The assistance and help received during the course of this investigation have been fully acknowledged.

Dr. Laxmi Rawat
Chairperson
Advisory Committee

Place: Ranichauri

CERTIFICATE-II

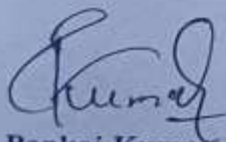
This is to certify that the thesis titled, "Evaluation of barnyard millet germplasm for morpho-metric characterization and screening against important endemic diseases in mid hills of Uttarakhand" submitted by **Mr. Neelam Pavan Kumar** I.D. No. **UUHF/21321** to VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India in partial fulfilment of the requirements for the degree of **Master of Science Agriculture** in the discipline of **Seed Science and Technology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner on **30.09.2023**.



Chairman of Advisory Committee
Dr. Laxmi Rawat

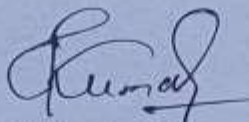


External Examiner
Dr. Arun Bhatt
Associate Professor
Department of Biotechnology,
GB Pant Institute of Engineering and
Technology, Ghurdauri, Pauri
Garhwal



Dr. Pankaj Kumar
(Co-Advisor)

Members of the Advisory Committee



OIC/Head of the
Department



Dr. R.K Prasad

Countersigned



Dean
College of Forestry,
Ranichauri

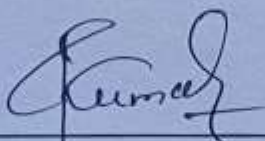
CERTIFICATE- III

This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, **“Evaluation of barnyard millet germplasm for morphometric characterization and screening against important endemic diseases in mid-hills of Uttarakhand”** submitted to VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India by **Mr. Neelam Pavan Kumar, Id No. UUHF/21321** in partial fulfillment of the requirements for the award of **Master of Science in Agriculture** in the discipline of **Seed Science and Technology**.



Dr. Laxmi Rawat

Chairman, Advisory Committee



(Signature & Name)

Head/OIC of the Department

College of Forestry, Ranichauri

ACKNOWLEDGEMENT

Acknowledgement in true essence, gives us an opportunity to remember and express our feelings for those whom we have and revere. When going gets tough and tougher, the helping hand offered then by all the near and dear ones is always remembered with gratitude. So, I will try to do my best to extend my great appreciation to everyone who gave me scientifically support, encouragement and contributed with me towards shaping this thesis. I am grateful to all of those with whom I had the pleasure to work during this period.

*I would like to give my first thanks to **Almighty GOD** and my parents, as without their blessings, accomplishment of my work and preparation of this thesis would have not been possible.*

*I take this rare opportunity to express my deep sense of gratitude, indebtedness and personal regards to **Dr. Laxmi Rawat, Assistant Professor, Plant Pathology**, College of Forestry, Ranichauri and chairman of my Advisory Committee for her valuable guidance, scholarly inputs and consistent encouragement I received throughout the research work. Her moral support, timely suggestions, affectionate attitude and above all her vast knowledge has helped me immensely to complete this research work. I am sincerely grateful to her for her affectionate encouragement and never ending patience.*

*From the inner core of my heart, I acknowledge **Dr. Pankaj kumar**, Assistant Professor, Department of Crop Improvement and **Dr. R. K. Prasad**, Assistant Professor, Department of Seed Science and Technology, worthy members of my Advisory Committee, for their guidance, encouragement and timely suggestions.*

*I am highly indebted to **Dr. Arvind Bijalwan**, Dean, College of Forestry, Ranichauri for his close supervision, their punctual inspirations, timely suggestions with kindness, enthusiasm and providing essential facilities to conduct the proposed investigation related to thesis.*

*It's an immense pleasure to express great, heartfelt respect to my beloved Teachers, **Dr. Pankaj Kumar**, Assistant Professor (Department of Crop Improvement), **Dr. Abhishek Panwar**, Assistant Professor (Department of Seed Science and Technology), **Dr. Sumit Choudhary** (Department of Agronomy) who have guided me all the way to reach up to this level and for their help, motivation and encouragement.*

*My heartfelt thanks to **Mr. Manoj Joshi (Project Fellow)**, **Mr. Sumit Chauhan (Senior Research Fellow)**, **Mr. Ajay Mamgain (Project Fellow)**, **Mr Ashish (Senior Research Fellow)**, **Mr Sandeep (Field Assistant)** and **Mr. Uttam Singh Negi (Office***

Aditya Pratiksha, Vaishnavi, Anchal, Jigyasa, Rahul and sachin for their encouragement, assistance and co-operation during my PG studies and thesis work. I cannot forget the love and co-operation received from my juniors Abhishek, Ankit, Shivani, Shalini, Priya, Shifa and Soumya.

Finally, I would like to acknowledge the people who mean world to me, my parents (Sri Neelam Yadagiri and Smt. Neelam kanaka laxmi) who stride hard and encouraged me even at the cost of their own comforts, held on to my hand and taught me everything I know today. I don't imagine a life without their love and blessings. Thank you, mom and dad, for showing faith in me and giving me liberty to choose what I desired. My heartfelt gratitude to my loving brother Neelam Praveen Kumar for cheering me up and who stood by me through the good times and bad.

I expressed my heartfelt gratitude and sentiments towards my sisters Munilowkhya and Alowkhya for the moral support, love, and their ever caring nature. I would always remember her loving attitude, which made me, overcome the obstacles effortlessly.

Last but not the least I am very thankful to each and every person who directly or indirectly helped me in completion of my thesis. I owe my heartiest thanks to them. All may not have been mentioned, but none is forgotten.

Date: 03-10-2023

Place: Ranichauri


Neelam Pavan Kumar
(Author)

CONTENTS

S.No.	Chapters	Page No.
1.	INTRODUCTION	1-4
2.	REVIEW OF LITERATURE	5-22
3.	MATERIAL AND METHODS	25-40
4.	RESULTS	41-68
5.	DISCUSSION	70-75
6.	SUMMARY AND CONCLUSIONS	76-79
	LITERATURE CITED	80-92
	APPENDICES	93
	ABSTRACT (ENGLISH)	95
	ABSTRACT (HINDI)	96
	VITAE	97

LIST OF TABLES

Table No.	Title	Page No.
3.1	List of barnyard millet germplasm used in the experiment	26
3.2	The details of experimental layout	29
4.1	Evaluation of barnyard millet germplasm for inflorescence colour, inflorescence shape and panicle compactness	45-46
4.2	Evaluation of barnyard millet germplasm for growth and yield related parameters	47-48
4.3	Evaluation of barnyard millet germplasm for grain smut, sheath blight, leaf blight and head smut disease under open field conditions	55-56
4.4	Evaluation of barnyard millet germplasm for seed related parameters such as seed length and seed width	57-58
4.5	Detailed information of various genetic components of barnyard millet crop	67

LIST OF PLATES

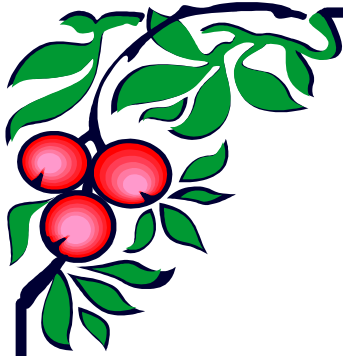
S. No.	Title	Page No.
1.	An overview of field experimental trail of 54 barnyard millet germplasm	27
2.	Recording of morphometric observations under field conditions	33
3.	Variation in inflorescence colour of barnyard millet	49
4.	Variation in inflorescence shape and panicle compactness of barnyard millet	51
5.	Important endemic diseases of barnyard millet under field conditions	61
6.	Data recording for the seed attributing traits of harvested seeds of barnyard millet germplasm	63
7.	Variation in barnyard millet seed coat colour	68

LIST OF FIGURES

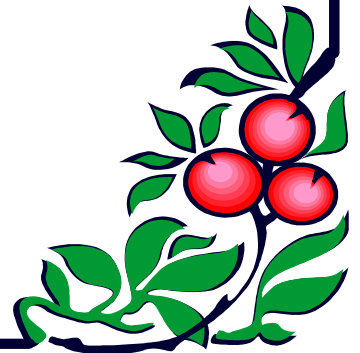
S.No.	Title No.	Page No.
1.	Detailed layout of each entry in field experiment	29
2.	An overview of experimental layout of each replication	30
3.	The phylogenetic tree of various morphometric seed characters of the barnyard millet germplasm	59-60

LIST OF APPENDICES

APPENDICES No.	Title	Page No.
1.	Meteorological data of College of Forestry, Ranichauri during <i>Kharif</i> - 2022.	93
2.	Analysis of variance (ANOVA) for evaluation of 54 barnyard millet germplasm on days to 50% flowering, days to maturity, plant height, number of basal tillers, number of productive tillers and panicle length.	94
3.	Analysis of variance (ANOVA) for evaluation of 54 barnyard millet germplasm on panicle weight, grain yield, fodder yield, 1000 seed weight, seed length, seed width, biological yield and harvest index.	94



INTRODUCTION



Although commercialization and mechanization of agriculture have benefited from adequate food supplies, they have also been observed to have negative side effects, notably with regard to the loss of agro-biodiversity and the maintenance of minor crops. It has been thought that a latent threat to global food security is the thinning of various crop species that contribute to the world's food supplies. Three major crops viz., rice, wheat and maize have accounted for 50% of the world's food needs, however, they majorly fulfil carbohydrate need of the body but lack most of the essential amino acids and minerals thus making them poor source of nutrients (**Kumar et al., 2021**). A lack of vitamins and micronutrients [zinc (Zn), magnesium (Mg), and iron (Fe)] in the diet disturbs millions of individuals around the world, causing them to experience hidden hunger (**Upadhyaya et al., 2014**). As an illustration, approximately half of the world's population suffers from micronutrient deficiencies, primarily as a result of the developed nations' excessive reliance on grains like rice, wheat and maize. A good way to diversify diets and lessen hidden hunger is to replace primary cereals with other crops that are higher in nutrients and have nutraceutical benefits (**Bhat et al., 2019**). The world needs more sustainable crop choices like millets to provide cheap sources of nutrient rich diet while also raising farmers' incomes. Due to their significant potential as a source of untapped nutraceutical characteristics and their potential to serve as an alternative food grain throughout most of the world, millets play a crucial role in achieving reasonable means for nutritional security (**Chauhan and Johnson, 2011**).

Millets are forage grasses which belongs to family poaceae (**Bunkar et al., 2021**). Minor millets [finger millet, *ragi* or *mandua* [*Eleusine coracana* (L.) Gaertn], barnyard millet or *jhangora* [*Echinochloa spp.* (L.)], foxtail millet, *kangni* or *kutki* [*Setaria italica* (L.)], kodo millet [*Paspalum scrobiculatum* (L.)], little millet [*Panicum sumatrense* (L.)], proso millet or *cheena* [*Panicum miliaceum* (L.)], and brown-head or brown-top millet [*Brachiaria ramosa* (L.)] is the group of small sized millets in opposite to major millets which includes sorghum [*Sorghum bicolor* (L.) Moench] and pearl millet [*Pennisetum typhoides* (L.)] of bigger grain size (**Joshi and Agnihotri, 1984; Maitra, 2020**). These crops are significant for their nutritional as well as therapeutic advantages, animal feed and their role as life savers in times

of food shortage (**Yenagi et al., 2010**). These crops often grown in semi-arid conditions with very little rainfall, with the help of shorter lifespan, and marginal or degraded soils with very low nutrient levels. They are already equipped with C4 photosynthetic processes which have higher capacity to produce dry matter and a high level of heat as well as drought tolerance which makes them rapidly adaptable towards damaged soils (**Yadav and Rai, 2013**). These coarse grain cereals are primarily grown by small and tribal farmers under rainfed farming conditions. Its distribution is found predominantly in the developing Asian, African and in some parts of European countries.

World production data accounts for 89.17 million metric tonnes (MT) of millets from an area of 74 million hectares (Mha). (**Anonymous, 2022**). Whereas in India these values are limited to a production of 17.3 MT of all millets from an area of 13.8 Mha. When we consider small or minor millets, the cultivation area reduces to 0.444 Mha and the production records to 0.346 MT, and a productivity of 789 kilogram per hectare. In Uttarakhand, small millets are being cultivated in an area of 0.049 Mha with a production of 0.071 MT with productivity of 1449 kilogram per hectare. (**Anonymous, 2021, Sangappa et al., 2023**).

Barnyard millet (*Echinochloa* spp.) belongs to the tribe Paniceae, under the sub family Panicoideae of the family Poaceae and having chromosome no. $2n=6x=54$ (**Clayton and Renvoize, 2006**). It is richest source of crude fibre and protein among the minor millets (**Rao et al., 2017**). Being a member of minor millet group, this also possess the property of tolerance towards water scarcity as well as partial waterlogged condition and so taken as a rainfed crop. (**Singh, 1983**). In India, it is mainly cultivated in Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu, Bihar, Punjab, Gujarat and Uttarakhand hills and in some parts of Karnataka and Andhra Pradesh. (**Ranjanna et al., 2020**).

Barnyard millet crop has a great adaptability and is cultivated during summer season (**Gupta et al., 2009**). The morphometric traits of this species have a greater adaptability in adverse conditions which includes the tall and robust stature of the plant having annual growing habit and attaining a height of about 2.2 m. It has a short generation time and completes its life cycle from seed to seed in 55 to 65 days, however, may take longer time under northern hill ecosystem (**Sood et al., 2015**). Leaf blades are flat and broad without ligules. The inflorescence is a terminal panicle growing up-to 10 to 25 cm long with dense racemes of 3 to 4 millimetres (mm) long spikelet (**Napper, 1965**). Spikelets are dioecious,

awned or awn less and short, scaberulous pedicels supported by two glumes. Grain is 2-3 mm long and 1-2 mm wide and enclosed in white shining hardened lemma and palea (**Mitich, 1990**).

Now a days millets are majorly affected by changing environment and the constraints faced by the producers of this crop are at an alarming rise viz., rain dependent farming, scattered land pattern, uneven topography, adverse weather conditions, lack of awareness towards the schemes and policies introduced by government for farmers' welfare as well as the benefits of cultivating minor millets, damage caused by wild animals, insect pests and diseases are some of the major problems resulting decline in production and productivity. Among these listed limitations, diseases like- leaf blight (*Helminthosporium crusgalli*), sheath blight (*Rhizoctonia solani*), grain smut (*Ustilago crusgalli*) and head smut (*U. crusgalli*) are the major limiting factors causing heavy yield losses in the mid-hills of Uttarakhand (**Kumar, 2016**).

Leaf blight in barnyard millet is caused by a fungal pathogen (*H. crusgalli*) manifesting some oval to irregular and light grey to dark brown lesions on the leaf sheath. The central portions of the lesions later became white to straw-coloured with narrow, reddish-brown margins that appeared as a series of coppery and tan coloured bands across the sheaths, giving a very distinctive banded appearance compared to healthy sheaths (**Pall et al., 1980**).

Sheath blight (*R. solani*) is another fungal disease-causing lesion which initially appear on the leaf sheaths near ground level, but quickly spread and coalesce to cover the upper leaf sheaths and causing foliage damage. The central portions of the lesions later turn white to straw coloured with narrow, reddish-brown borders which appears as series of copper and brown colour bands across the leaves. High relative humidity (>70%) and temperature between 28 to 30°C are known to favour the development of banded leaf and sheath rot (**Nagaraja et al., 2007**). The percent loss of grain yield due to sheath blight has been reported up to 50-60% (**Jain et al., 2010**).

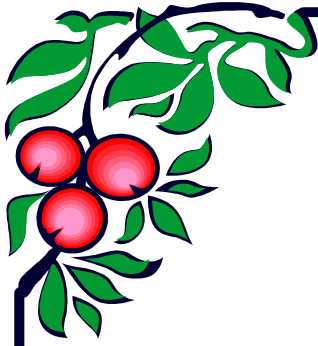
Grain smut is caused by *U. crusgalli* which infects the panicle that causes bulged flower like ovaries, which are round and hairy, to enlarge twice or thrice then the normal size. Whereas, sometimes gall like swellings are also observed at nodes, stem and older leaves (**Sood et al., 2015**). (**Kumar, 2013**) observed up to 60 percent loss of yield caused by this grain smut disease. The affected seed enlarges 2 or 3 times of the normal size and their surface

becomes hairy. This disease appears at the time of grain formation when the temperature ranges from 20-25°C. Head smut disease is caused by *U. crusgalli* where infected inflorescence is deformed and produces gall like swellings on the stem and the nodes of young shoots as well as in the axils of older leaves, infected panicles may be enclosed in a flag leaf and may not emerge fully (Nagaraja *et al.*, 2007). The percent of yield loss caused by the head smut was reported up to 30% by (Lilian *et al.*, 2016).

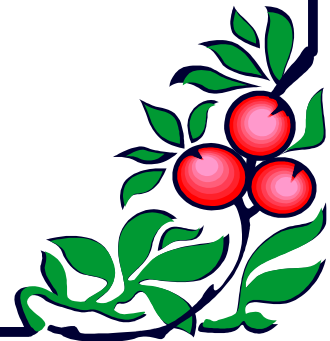
Genetic variability in the gene pool has a significant impact on genetic improvement for yield and yield traits in any breeding programme. Barnyard millet has been under-utilised despite having potential as a food and fodder crop because its genetic resources have not been fully explored. It is a vital to efficiently use genetic resources to develop improved cultivars of barnyard millet, it is necessary to assess the level of genetic variability and choose superior genotypes with desirable characteristics. The morphometric characterisation serves as base for evaluating, describing, and categorising germplasm collections and the germplasm is an essential reservoir of desirable alleles for both quantitative and qualitative characteristics. The evaluation of germplasm will meet the needs of long-term plant breeder goals such as duplicity of germplasm, resistant donors for diseases, depleting natural resources, and climate change. Therefore, documentation of the available germplasm will be more crucial to the crop breeding programme to serve the near future. To identify the extent of genetic differences within and between crop species, qualitative and quantitative assessment of genetic variability is necessary. (Adugna, 2002; Geetanjali *et al.*, 2023).

After considering the above certainties and potentials, an investigation regarding the **“Evaluation of barnyard millet germplasm for morpho-metric characterization and screening against important endemic diseases in mid-hills of Uttarakhand”** was carried out on 54 genotypes of barnyard millet at Plant Pathology Block, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand with the following objectives: -

1. To study the morphometric characterization of barnyard millet germplasm.
2. To screen barnyard millet germplasm for important endemic diseases viz., sheath blight, leaf blight, grain smut and head smut.
3. To study the morphological traits of seeds obtained from harvested barnyard millet germplasm.



REVIEW OF LITERATURE



An attempt has been made to review the work done by earlier researchers around the globe to study the “Evaluation of barnyard millet germplasm for morpho-metric characterization and screening against important endemic diseases in mid-hills of Uttarakhand” through the available literature present over the different online and offline sources. The following material covers a thorough outline of the proposed research work:-

2.1 Morphometric characterization of barnyard millet germplasm.

Thakur and Saini (1995) evaluated broad sense heritability for six yield component traits across four genotypes. Days to 50% flowering, plant height, and days to maturity revealed significant genetic progress in 90 ragi lines.

Bendale *et al.* (2002) studied the genotypic and phenotypic coefficient of variation on 14 quantitative characters using 29 diverse genotypes of ragi. Coefficient of variation (PCV and GCV) were recorded high in number of productive tillers, straw yield, weight of grains, grain yield.

Kumar *et al.* (2002) analysed 30 genotypes of finger millet and discovered a significant difference between the GCV and PCV for basal tillers, fodder yield, and variables like days to maturity, grain yield, and 50% flowering, all of which exhibited strong heritability, and a moderate to low level of genetic progress.

Patnaik *et al.* (2004) conducted an experiment on five genotypes (GPU-26, GPU-28, Indaf-9, HR-374 and L-5) to evaluate the heritability and genetic advance and reported that genetic advance was high for seed weight, days to 50% flowering and panicle length.

Nirmalakumari *et al.* (2010) evaluated 109 genotypes of little millet and also studied on genetic variability and other genetic traits, The results showed that high estimates of variability, high heritability, and high genetic advance were seen for grain yield, the number of productive tillers, and other genetic traits.

Sao *et al.* (2010) examined the heritability and genetic advance for 8 yield component parameters, 27 genotypes of kodo millet were examined. For the traits' days to maturity, number

of panicles, days to 50% flowering, and plant height, the coefficient of variation was moderate, whereas it was high for fodder yield and grain yield. The results showed that for days to 50% flowering, length of panicles, days to maturity, fodder weight, and grain production, there was a high heritability in conjunction with a high genetic progress.

Ganapathy *et al.* (2011) found that PCV and GCV levels were high in productive cultivars per plant and moderate for traits such as days to 50% flowering, plant height, panicle length and grain yield per plant. Low PCV and GCV were observed for days to maturity. High heritability with high genetic variance observed in days to 50% flowering, plant height, productive cultivars and seed yield per plant.

Arunachalam *et al.* (2012) studied eighteen breeding lines in three diverse environments of Tamil Nadu namely Coimbatore, Madurai and Chettinad. Among the three locations, Coimbatore and Chettinad turned out to be high and low yielding environment respectively. The variance analysis inferred that the performance of barnyard millet lines was influenced by the growing environment. The entries TNAU 130 and TNAU 146 performed well in favourable environment for grain yield. High grain yield was observed in the genotypes of VL 222, VL 232, VL 221, VL 224 and VL 230 at Coimbatore location. On the contrary, the stability parameters indicated that these entries were not consistent in yield performance. The variety CO (kv) 2 performed well in unfavourable condition with mean yield of 16.44 q ha⁻¹.

Haradari *et al.* (2012) evaluated genetic variation in 1000 finger millet accessions with 11 quantitative traits in grain yield per plant and found large significant differences among all finger millet genotypes for various characters. A close relationship between GCV and PCV was observed for most characters. High heritability was expressed by plant height and Days to 50% flowering. Genetic growth per plant, grain yield per plant, straw yield per plant and plant height.

Dikshit and Nizar (2013) studied the variation in quantitative characteristics of small millet showed considerable variation treatment adjusted between treatments, between controls and treatment versus control. Morphological and agronomic data showed significant differences in all traits studied. High CV was observed at plant height (26.49%), followed by inflorescence length (10.19%). Between the links investigated, IC 340246 - a tall, late maturing accession with a high index score of 25 was identified as promising for future crop improvement program.

Joshi (2013) worked on diversity and extent of variability for different morphological and

yield related traits in barnyard millet (*Echinochloa* spp). A wide range of variability were observed for all the characters studied in 58 diverse genotypes including PRJ-1 a variety were originally procured from world collections of barnyard millet being maintained at International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad. A significant variation was detected for genotypes for all traits suggested that there was considerable variability among the genotypes. It was observed that characters viz., days to maturity (73-90 days), Number of productive tillers (2-15), ear length (9-21 cm), grain yield per plant (0.35-26 g). Other traits also exhibited great deal of variability and in terms of range and mean and coefficient of variance.

Yadav and Yadav (2013) studied the performance of four jhangora genotypes belonging to two different species viz. *Echinochloa frumentacea* species VL 207, VL 172 and *Echinochloa utilis* species PRB 401, PRJ-1 in four different soils and to identify the most suitable variety for dual use. The results showed that the height of the plant gradually increased when the nitrogen dose was increased. Genotype PRJ-1 had the highest grain and forage yield (2143 and 6427 kg/ha), while VL 127 (1677 and 5182 kg/ha) had the lowest, PRJ-1 had the highest average of 1000 seeds weight (4.8 g), the results concluded that genotypes PRJ-1 and PRB 401 belong to Japanese barnyard millet, have high potential compared to (jhangora) Indian field millet genotypes (VL 207 and VL 172) and can also be recommended for cultivation in Uttarakhand hills, crop intended for nutrition and food security.

Ulaganathan et al. (2014) studied 100 accessions of germplasm from five standard varieties and It was observed that high PCV and GCV values were recorded in grain yield per plant (23.96 and 22.74%). The high heritability ranged from 63.95 to 96.27%, indicating that the characters were relatively less influenced by environmental factors and phenotypic selection. Better heredity with higher genetic development observed in plant grain yield (58.47%), productive cultivars which are 44.45% and thousand kernel weight (29.70).

Prakash and Vanniarajan (2015) worked on 65 millet genotypes to determine the relationship study of characters and their direct and indirect effects on grain yield/plant. The results were presented in this ear head weight had the maximum direct effect on grain yield/plant, followed by straw yield/plant, ear head length and height of the plant.

Sood et al. (2015) studied a total of 95 germplasm lines from the worldwide collection for qualitative and quantitative characteristics for two rainy seasons in Almora, Uttarakhand, India. A large variation was observed in days to maturity, grain weight of the five ears and yield

components.

Anuradha et al. (2017) studied on analysis of variance of 30 little millet genotypes and the results revealed that coefficient of variation of genotype reported highest grain yield (23.52 q/ha), while coefficient of variation of phenotype reported highest grain yield (26.61 q/ha). Heritability for plant height ranged from 0.67 to 0.99 (days to 50% flowering and days to maturity), while it was 0.78 for yield. There was evidence that the number of tillers per plant, panicle length, and fodder yield were all strongly and positively related to grain yield.

Arya et al. (2017) worked on 35 different millet genotypes including three controls viz. VL-172, VL-207 and PRJ-1. Observations were recorded for growth, yield and seed quality parameters respectively, phenotypic and genotypic correlations of traits were assessed for biological yield per plant, weight of 1000 seeds, grain yield per plant. The data were used to estimate correlation coefficients. Biological yield per plant, 1000 seed weight resulted in a very strong positive correlation with grain yield per plant at the phenotypic and genotypic levels. The greatest positive direct effect on grain yield per plant was determined by biological yield per plant and yield index at the genotype and phenotype level. However, a large negative direct effect was observed at the genotype level for flag leaf area and number of fingers per ear.

Nirubana et al. (2017) studied on 103 germplasm accessions of kodo millet and evaluated the genetic variability, heritability and genetic advance for 15 yield components, and the results revealed that high phenotypic and genotypic coefficient were high for grain yield, number of productive tillers and panicle length. The broad sense heritability ranged from 97.30% for Days to 50% flowering. Plant height, the number of basal tillers, the number of productive tillers, length of the inflorescence all showed high heritability together with high genetic progress as a percentage of the mean.

Trivedi et al. (2017) evaluated the diversity of millet (*Echinochloa frumentacea*) to find out the trait diversity and abiotic stress tolerance caused by different traits and to determine the trait-specific additions for yield improvement and also for the cultivation of millets in the region. as well as other similar agroecological areas. A total of 178 accessions were collected and evaluated for several morphophysiological and biochemical traits. Significant variation was observed in days to 50% flowering, days to 80% maturity, 1000 seed weight and germplasm yield. These characteristics are considered decisive for the adaptation of new varieties to different agricultural and climatic conditions.

Manimekalai *et al.* (2018) evaluated the 61 barnyard millet genotypes from South India, using 10 morpho-nutritional traits and 51 expressed sequence tags (ESTs) – simple sequence repeats (SSRs) observed in the morpho-agronomic and nutritional characteristics of the grain, including important characteristics such as flowering (49.50-82.00 cm), plant height (58.17-152.38 cm), grain yield (12.52 g–41.25 g).

Patel *et al.* (2018) evaluated the thirty two genotypes of little millet were studied for genetic variability of different morphological and biochemical traits viz., days to 50 % flowering, days to maturity, plant height at maturity (cm), 1000 seed weight (g), number of productive tillers per plant, , panicle length (cm), fat content (%), grain yield per plant(g), straw yield per plant (g). The results of the present study indicated all the sixteen characters had a wide range of variability in the different little millet genotypes. High estimates of genotypic and phenotypic variance were observed for days to 50% percent flowering, plant height at maturity, panicle length, straw yield per plant, days to maturity. High genotypic and phenotypic coefficient of variation found in number of productive tillers per plant, grain yield and straw yield per plant.

Dhanalakshmi *et al.* (2019) studied on 95 including millet genotypes and 2 commercial control cultivars namely MDU1 and CO (KV) 2 of jhangora crop, were evaluated in saline soil. showed a significant difference for all characters studied. High phenotypic coefficient of variation, genotypic coefficient variability and heritability were recorded for plant height, panicle length, grain yield per plant. Association studies showed that grain yield per plant was a highly significant positive correlation days to 50 percent flowering, days to maturity and 1000-grain weight.

Ranjana *et al.* (2020) studied on 87 germplasm accessions of barnyard millet along with two checks (VL181 and PRJ-1). Data were collected for 13 morphological and 10 yield-attributing traits. The majority of germplasm entries show the presence of culm branching and a concave grain shape. Most of the accessions show pyramidal inflorescences of green color and compact racemes with grey or light grey veins. The mean phenotype was demonstrated by the germplasm in terms of the presence or absence of pigmentation on internodes and leaf sheaths and a straight or curved shape of the lower raceme. Accessions for all traits showed a wide range of mean values. High PCV and GCV were recorded along with high heritability and high genetic advancement as percent of mean, indicating the predominance of additive effects in the expression of these traits and a high efficiency of phenotypic selection for these traits.

Vikram et al. (2020) worked on 40 mutants along with two check varieties CO(Kv)2 and MDU1 of barnyard millet crop during *kharif*- 2019. Sixteen characters were studied and out of which only 11 traits showed significant variation. Among the eleven biometrical traits, high heritability was recorded by traits such as number of basal tillers, days to fifty percent flowering, flag leaf length, plant height, number of productive tillers, ear head weight and single plant yield. Correlation studies showed that number of productive tillers, ear head weight and plant height possess significant positive correlation with yield at both genotypic and phenotypic level. Thus, selection of these traits would be rewarding for yield improvement in barnyard millet.

Gajalakshmi et al. (2022) evaluated the effect of different levels and methods of zinc fertilization on improving the growth and yield of jhangora at different growth stages, and from the results it was concluded that the use of soil NPK 20 kg ZnSO₄ ha⁻¹ was more successful in crop. plant height (157.0 cm) and other morphological traits and performance characteristics such as, panicle length (17.6 cm), panicle weight (29.2 g) and 1000 seed weight (3.89 g) of millet. Grain yield (2606 kg ha⁻¹) and straw yield (3411 kg ha⁻¹) were also observed with soil-based NPK application of 20 kg ZnSO₄ ha⁻¹, which was 27.1% more than NPK.

Raju et al. (2022) evaluated the 40 germplasm accessions of barnyard millet crop at different geographical region, and the results revealed that Phenotypic coefficient of variation (PCV) was greater than Genotypic coefficient of variation for traits such as days to flowering, plant height, days to maturity, number of basal tillers, inflorescence length, single ear head weight, and grain yield per plant, high heritability along with high genetic advance was demonstrated. While shorter raceme length indicated moderate heritability with high genetic advance, traits like thousand grain weight expressed moderate genetic advance with high heritability.

2.2 Screening of barnyard millet germplasm for sheath blight, leaf blight, grain smut and head smut diseases.

Jain (1995) conducted a field trail for the control of head smut disease in kodo millet crop. The causal agent of these disease is *Sorosporium paspali-thunbergii*. Cultivars DPS 34, DPS 77 and DPS 104 were identified as resistance sources for head smut. Bavistin 25 SD [carbendazim], Dithane M45 [mancozeb] and Parasol [phenylmercury acetate] at 2 g/kg seed

gave the best disease control. Early sowing resulted in higher disease incidence than late sowing, but gave better yield.

Jain (1999) evaluated in a field trial for the control of head smut. Four fungicides namely Chlorothalonil (Kavach 75 WP), carbendazim (Bavistin 50 WP), tebuconazole (Raxil 25 WP) and methoxyethyl mercury chloride (Emisan 6) were tested along with an untreated control to prevent the occurrence of head smut. disease incidence varied from 0.2 to 18.5% were recorded in different treatment. All fungicides significantly reduced head smut by 75.3 to 98.9% and increased yield by 11.6 to 25.3% compared to the control treatment. Carbendazim, chlorthalonil and emissan at 2 g/kg seed were most effective at less than 1% incidence. The highest grain yield (2152.3 kg/ha) was recorded with carbendazim treatment but it was not significantly better with raxill (2034.6 kg/ha), emisaan (2021.4 kg/ha) and chlorthalonil (1991.8 kg/ha), final results concluded that seed treatment with Carbendazim, chlorthalonil and emisan @ 2 g/kg can be used for combat and maximum grain yield.

Yadava and Jain (2002) conducted an experiment to assess yield loss due to grain smut (*Ustilago panici-frumentacei*) in jhangora (*Echinochloa frumentacea*). Among the 13 genotypes tested, K 1 was resistant and had minimal yield loss. (RAU10 and RAU 11) caused the maximum yield loss. Average yield loss varied between 6.5 to 60.8% in different genotypes. Both disease incidence and severity were significantly and positively correlated with grain yield loss, but severity had a greater effect.

Jain and Tripathi (2007) examined the Grain smut during the survey, and the *Macalpinomyces sharmae*, the causative agent of this disease, is a serious disease of small millet, which causes a significant reduction in grain yield. The average prevalence of grain smut varied from 5.9 to 31.0% and 5.0 to 7.8%. Early maturing cultivars OLM 20, OLM 23, OLM 45, DLM 80, DLM 93, DLM 314, DLM 369 and RLM 36 and JK 8 were found to be susceptible to grain smut. Varieties whose ripening time was more than 100 days were recognized as completely free. A decrease in grain yield was found in different cultivars from 9.8 to 53.55%, while plant height decreased from 4.2% to 16.6% and panicle length from 6.4 to 38.9%. Seed treatment with carboxin @ 2 g per kg of seeds with one foliar spray of carbendazim (0.05%) was found to be most effective followed by seed treatment with one foliar spray of carbendazim. (0.05%), but highest B:C ratio was recorded in seed treatment with carbendazim only @ 2 g/kg seeds.

Kumar et al. (2008) screened the smut disease and its main impact on seed in the form of seedborne disease. The spores adhere to the surface of the grains and infect the seedlings. Two types of smuts are reported on barnyard millet, head smut (*Ustilago crus-galli* Tracy & Earle) and grain smut (*Ustilagopanicifruentacei* Brefeld). Head smut is recently reported from Uttarakhand in India. Both of the diseases are seed-borne and can be managed through seed treatments.

Kumar and Dinesh (2009) reported that a new disease named sheath blight is caused by *R. solani*. However, during 2012 routine survey of minor millet diseases was done in the Tehri-Garhwali region (Uttarakhand, India). Classic burn symptoms were also observed on the leaves of jhangora. The new symptom was new, appearing as oval to irregular and light grey to dark brown lesions on leaves. The results were revealed by cultural, morphological and microscopic studies and the pathogenicity test of the pathogen.

Gupta et al. (2010) worked on 257 germplasm of barnyard millet crop which were inoculated with grain smut spores at anthesis stage during 2003. Seed produced on inoculated ear heads was sown in 2005 and resulting plants evaluated for ten morphological traits and grain smut incidence. The accessions were grouped into seven groups based on origin. The lowest mean grain smut incidence was recorded for advance breeding lines, while highest mean value was observed for Uttarakhand group. Genes determining grain yield and susceptibility to grain smut were at most loosely linked as evidenced by non-significant correlations between grain smut incidence and grain yield in six out of seven groups as well as whole collection. Smut resistance along with grain yield in barnyard millet can be enhanced by adopting proper breeding strategy; therefore, in segregating generations, selection should be carried out for both characters simultaneously.

Nagaraja and Reddy (2010) studied the Leaf blight caused by *Rhizoctonia solani* was first seen during 2006 kharif in a farm in Narasapura village, Kolar district, Karnataka. The disease appeared as oval or irregular light to dark lesions on the lower leaf sheath. Later, a white straw with a narrow reddish-brown border lesion. Regularly spreading spots were also visible on the leaf blades. Irregular to oval, dark brown to purple necrotic lesions occurs on stems, fingers and peduncles. *Rhizoctonia solani* was produced by the pathogen that was isolated from several damaged plant sections.

Kumar (2011) examined, first instance of Foxtail Millet Smut Disease observed, on the basis of microscopic examination and relevant literature, the fungus was identified as *Ustilago* sp. Based on the morphological characters disease has been recognised, the disease has been reported from Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra. However, the disease has been recorded for the first time from Uttarakhand.

Kumar (2012) evaluated the nine genotypes of barnyard millet were resistant to *Helminthosporium* leaf spot, grain and head smut under natural epiphytic conditions. Evaluation of test genotypes against *Helminthosporium* leaf spot or leaf spot was performed on a 0-5 scale rating. Out of nine genotypes, only two genotypes viz. TNAU 130 and VL 222 were completely free of *Helminthosporium* leaf blight or leaf spot. But four genotypes namely; TNAU 116, VL 172, VL 29 and VL 221 showed resistant response while two genotypes viz. VL 220 and TNAU 128 showed a moderately resistant or sensitive response. The local variety showed a susceptible response.

Jain et al. (2013) studied a total of 81 accessions of kodo millet (*Paspalum scrobiculatum*), including one national control (GPUK 3), were evaluated for resistance to head smut caused by *Sorosporium paspali-thunbergii*, and the (% disease incidence ranged in between 0.0-29.8% in three consecutive years. Based on three years of data collected, none of the cultivars was completely free of infection, and an incidence of 0.2-12.6% was recorded in all accessions. Three accessions namely 64, 348 and 424, were found to be resistant to head smut with a prevalence of less than 1.0%. Fifty-one cultivars were moderately resistant, 23 moderately susceptible, and 5 susceptible to head smut. GPUK 3 was found to be sensitive to head smut.

Jain et al. (2014) studied the Seventy-two foxtail millets collected from geographical areas of Madhya Pradesh were evaluated along with two check varieties namely SIA 326 and PS 4 against the sheath blight and leaf blight through the artificial inoculation method. The severity of the disease varied from 10.8 to 68.9%. Cultivars namely RFM 82, 83, 84, 85, 87, 88, 90, 93, 94, 95, 96 and 97 are resistance, in this contrast, leaf blight and sheath blight was moderately resistant to 21 land races, moderately susceptible to 29 others, and one was highly susceptible to 11 were susceptible. Average plant height was recorded 106.5 cm in resistant, 96.7 cm in Moderately resistant, 86.3 cm in moderately susceptible and 79.9 cm in susceptible and 76.4 cm in highly susceptible land races.

Joshi et al. (2014) worked with 428 landraces collected from 7 districts of Madhya

Pradesh and evaluated for agro-morphological in two consecutive years in 2009 and 2010. Wide variation in plant height, Days to maturity, grain yield per plant and reported 1000 grain weight. The average period of maturity ranges from 90.5 to 107.5 days. According to biotic stresses, the prevalence of shoot fly, head smut and sheath blight was recorded in the range of 2.1-60.7%, 2.1-39.1%, 13.7-49.5% respectively. A high coefficient of variation (CV) was recorded for shoot fly incidence (65.3%), followed by head smut incidence (43.6%), basal tillers (30.9%) and grain yield per plant (21.2%), while lowest CV was observed viz., days to maturity (2.6%), followed by days to 50% flowering (3.9%) and 1000-grain weight (7.9%). Desirable traits such as earliness, higher grain yield, higher test weight and non-shattering types were recorded in 15.9, 8.2, 18.7, 3.3 and 57.7% of landraces, respectively. In addition, landraces resistant to head smut (3.3%), *Rhizoctonia* species (Sheath blight) (11.0%) and shoot blight (11.2%) were identified.

Das et al. (2016) observed that the leaf blight its causal organism is *Helminthosporium crusgalli* disease symptom is purple to red spots with irregular margin and straw-colored centre. Spots may coalesce to form large lesion.

Kumar (2016) screened the various diseases, during surveys, he observed Grain smut, head smut, leaf blight and sheath blight in barnyard millet crop. And the result revealed that head smut was confined only in experimental trails of plant pathology and sheath blight was limited only to variety PRJ 1.

Kumar (2016) studied that status of major diseases in small millet and also to detect the emergence of new biotic problems in small millet over time. Based on surveys conducted between 2007 and 2012, *Cercospora* leafspot (*Cercospora eleusinis*), blast in finger millet, grainsmut (*Ustilagopanicifruentacei*), leafblight (*Helminthosporium monoceros*) of barnyard millet, leaf blight (*Cochliobolus setariae*) of foxtail millet, blight (*Bipolarispanici-miliacei*) of prosomillet and other diseases were recorded in Uttarakhand.

Lilian et al. (2016) studied the Head smut caused by *Tolyposporium penicillariae* Bref. And to estimate the losses in grain yield due to head smut at varying levels of susceptibility in 50 promising advanced pearl millet genotypes. Results showed that among the tested genotypes, KAT PM1 and ICMV 221 were resistant checks and showed minimum yield loss as compared to the susceptible genotypes, (SDMV 94001 and SDMV 94014) which had highest yield loss. The mean grain yield loss varied between 6.5 and 60.8% in different genotypes. Both incidence and

severity of the disease were significantly and positively correlated with losses in grain yield but severity contributed more. The prediction models for estimating yield losses were derived from yield in protected plots compared to none protected plots. Results showed that yield and disease severity were highly significant among the genotypes tested ($F_{pr} < 0.001$) with yield ranging from 1172-4122 kg ha⁻¹. The overall yield loss due to head smut was 18 percent.

Patil et al. (2016) studied the germplasm accession's little millet variety WV-125 is a pure line selection. Overall grain yield has increased by 8.77% (2864 kg/ha) compared to the regional check variety GV-2 (2633 kg/ha) and by 43.92% compared to the national check variety CO-2 (1990 kg/ha). When compared to local check variety GV-2 and national check variety CO-2, this culture is moderately resistant to diseases including Blast (Leaf, Neck, and Panicle), as well as moderately resistant to grain smut (%) and sheath blight.

Tripati and Jain (2016) studied the Head smut of Kodo millet (*Paspalum scrobiculatum* L.), and also the effect of head smut incidence on morphological and growth parameters of 12 kodo millet cultivars possessing various degrees of resistance and susceptibility. Different crops have reported phenotypic variations in the host plant as a result of the presence of smut-causing pathogens. Significant variation in morphological traits was discovered, proving that the current kodo millet cultivars are genetically diverse. Tillers per plant decreased from 0.0 to 37.2% and plant height decreased from 1.5 to 9.8%, respectively. In healthy and Smut-infected plants, the average crop growth rate (CGR) between 30 and 60 DAS was higher than the growth period between 60 and 90 days. CGR reductions between 30 and 60 days ranged from 1.2 to 20.8% and between 60 and 90 DAS, from 1.7 to 19.1%. Compared to resistant cultivars, susceptible cultivars demonstrated a greater drop in CGR. Infected plants with smut showed more pronounced effects on growth indices and morphological features.

Divya et al. (2017) conducted survey to identify the source of resistant against rust caused by *Rhizoctonia solani*. No cultivar/line was found to be resistant to *R. solani*, whereas sheath blight intensity was recorded, result shown that BL150 followed by TNPSU 174 and DLM 95 has more disease intensity level.

Divya et al. (2017) conducted a field trail with 15 small millet varieties of different maturity groups, the local sensitivity test OLM 203 (84.67%) was examined in natural field conditions to determine the susceptible. Among them, minimum percentage of disease intensity was recorded in BL 150 (40.00%) followed by TNPSU 174 (49.33%), DLM 95 (50.67%) and

maximum disease intensity was recorded in DHLT 28-4 (93.33%). Examined millet genotypes of different maturity stages and reported that RLM 43 is the resistant genotype and JK 8 is the susceptible genotype. The results showed that among the small millet germplasm against *Rhizoctonia solani*, no cultivar/lines were found to be resistant to *R. solani*, while the minimum percent disease intensity of banded sheath blight was recorded at BL 150 (40.00%) followed by TNPSU 174 (49.33%), DLM 95 (50.67%) and maximum disease intensity was recorded at DHLT 28-4 (93.33%).

Kumar et al. (2017) conducted 3 field trials to screen small millet germplasm under field conditions. Six pre-released and released varieties, DhLTMV 36-3, Kadiri 1, KOPLM 53, OLM 203, GPUL 1 and GPUL 2, were free from kernel smut and seven namely BL 8, TNPSU 171, TNPSU 170, BL 6, BL 41-3, DhLTMV 10-2, TNAU 160 are resistant. Four entries namely TNAU 163, TNAU 176, TNAU 178, OLM 203 were free and RLM 208 was resistant to covered smut. Fourteen landraces were resistant from covered smut namely RLM 175, RLM 177, RLM 179, RLM 182, RLM 186, RLM 189, RLM 203, RLM 204, RLM 211, RLM 225, RLM 226, RLM 228, RLM 232, RLM 231 and 28 were resistant with susceptibility index of 5.0. Among 100 landraces, 13.9% were highly resistant, 27.7% resistant, 41.6% moderately resistant, 11.9% sensitive and 4.9% very sensitive to kernel smut. Fourteen land races namely RLM 175, RLM 177, RLM 179, RLM 182, RLM 186, RLM 189, RLM 203, RLM 204, RLM 211, RLM 225, RLM 226, RLM 228, RLM 231, RLM 232 were completely resistant to grain smut.

Patro et al. (2017) evaluated genotypes of Proso millet (*Panicum Miliaceum* L.) against sheath blight caused by *Rhizoctonia solani*, Kuhn under in vivo conditions. Among the eleven genotypes tested, the minimum disease severity (64.00%) was recorded in TNAU 145 followed by TNPM 234 (73.33%), while it was 90.67% in the control. Genotypes TNAU 145 and TNPM 234 are equivalent to each other, while TNPM 234 is equivalent to TNAU 151, GPUP 24, TNPM 238 and GPUP 21.

Rehman et al. (2017) studied a significant disease of wheat is loose smut, which is caused by *Ustilago tritici*. A variety of wheat lines were tested during the current research for resistance to the lethal disease, and the results revealed that there was not a single line in the wheat genetic resources that was resistant to loose smut. Instead, the majority of the types exhibited susceptible to very susceptible responses. All of the environmental factors were shown to be favourable for the disease to develop. The disease poses a severe threat to wheat growth.

Jain et al. (2018) studied the status and management of banded leaf and sheath blight of little millet caused by *Rhizoctonia solani*. The mean disease and frequency ranges between 6.9 and 18.8% and 26.1 and 75.4%, respectively were recorded during the Survey. The banded leaf and sheath blight average disease incidence was highest (13.7%) and lowest (61.1%) in the fields of Satna District and Anuppur District, respectively. It was discovered that utilising unconventional chemicals might lessen the disease's severity and infection rate.

Kadam and Sharma (2018) conducted research to identify diseases and their severity. Different samples were collected and separated. The pathogen was identified based on symptoms, microscopic examination and pathogenicity test. *Drechslera setariae* has been identified as the pathogen of leaf blight. The leaf rust pathogen was identified as *Uromyces setariae-italicae*. It is concluded that the main diseases of foxtail millet were blight (*Cochliobolus setariae*) and rust (*Uromyces setariae italicae*), which were observed in serious association in some genetic structures. The effectiveness of fungicides and bioagents against *Cochliobolus setariae*, the causative agent of foxtail blight, was investigated using the spore germination technique.

Patro et al. (2018) studied the 11 kodo millet varieties including check were evaluated for resistance to banded blight in under field condition. None of the test lines or types were immune or extremely resistant, according to the screening of banded blight, BK 48 (53.33) and TNAU 86 (53.33) were listed as having a moderate susceptibility. Co 3 (92.00) (local) was found to be extremely susceptible, whereas varieties BK 36 (80.00) and RK 64 (80.00) recorded the highest disease severity. The percent disease severity reported 53.33% in the varieties (TNAU 86 and BK 48) to 80.00% (BK 36 and RK 64), whereas the susceptible check has a highest disease severity of 92.00%.

Patro et al. (2018) conducted a field experiment for the management of banded sheath blight disease in kodo millet by using potential biocontrol agents viz., *Bacillus subtilis*, *Pseudomonas fluorescens* and *Trichoderma asperellum*. The lowest sheath blight intensity (49.33%) was recorded in T7 (*P. fluorescens*, *T. asperellum* and *B. subtilis* were value-added in soil along with one kg talc mixture mixed with 25 kg FYM or vermicompost, incubated for 15 days) followed by 53.33% in T1 (seed treatment with *Trichoderma asperellum* @ 10 g/kg) and highest (61.33%) in T6 while it was 76.00% in control. Both high grain yield (1274.07 kg/ha) and fodder yield (2233.33 kg/ha) were found in T7, on average, among all the sites, the lowest intensity of sheath blight (22.11) was recorded in T7 (value-added soil *P. fluorescens* *T.*

asperellum B. subtilis one kg of talc mixed with 25 kg of FYM or vermicompost incubated for 15 days) and the highest (31.31%) in T3, while it was 41.24% in the control treatment.

Patro et al. (2019) conducted a field trial on fourteen barnyard millet varieties including check were evaluated for resistance to banded blight under field condition, none of the test lines or types were immune or extremely resistant, according to the screening of banded blight. The susceptible check result was 98.0%, however DHBM 33 (53.8%) and VL 254 (61.7%) were classified as susceptible. The disease intensity varied from 53.8% (DHBM 33) to 97.5% (TNEF 204), with a resistance rate of 11.4% (PRB 903) and a susceptibility rate of 98.0% (LDR-1).

Upamanya et al. (2019) evaluated the finger millet response of different cultivars i.e., PR 1639, KMR 652, WN 562, VR 1117, GSMC 1 and GPU 67 against serious diseases, e.g., leaf spot, Cercospora leaf spot, seedling and leaf spot and band spot. Cultivar PR 1639 had the highest severity of leaf blast (29.06%) and Cercospora leaf spot (8.55%). Cultivar VR1117 outperformed as compare to other cultivars for all observed disease severities. Highest severity of seedling and leaf blight and banded blight was observed in the variety GSMC 1.

Jain and Joshi (2020) evaluated the *Rhizoctonia solani*'s banded leaf and sheath blight, which affects the susceptible variety (JK 155) of kodo millet, can be controlled by seed treatment alone combined with one foliar spray in the field. Several treatments showed a significant change in relative lesion height (%) and grain yield. It was discovered that seed treatment with validamycin (2g per kg of treated seeds) followed by one foliar spray (0.2%) increased grain production by 25.8% over check variety while lowering disease severity by 85.3%, by reducing the disease severity by 78.2 and 76.8%, respectively, seed treatment and one foliar application spray of hexconazole (0.2%) and propiconazole (0.2%) were at par with and the next best treatments after validamycin.

Kumar (2020) examined the diseases of barnyard millet (*Echinochloa frumentacea* L.) and their management options. *Ustilago crusgalli* is the cause of the head smut disease of barnyard millet. The pathogen also affects *Echinocloa colonum*. The United States and India have both recorded cases of head smut. The diseased ear heads have been completely damaged and distorted. Drechsler made the first observation of leaf spot or blight in the United States in 1923. On flag leaves, the illness manifests as sporadic, spindle-shaped, isolated dark brown patches. B. Kumar and D. Prasad from Uttarakhand, India, initially described the sheath blight disease of barnyard millet. In the leaf sheath, the disease causes oval to irregular, light grey to dark brown

lesions.

Patro et al. (2020) conducted a Field experiment of 11 proso millet types, including check, were assessed for banded blight resistance in outdoor conditions. None of the test lines or varieties were found to be immune, highly resistant, or resistant after the screening. Every variety was vulnerable. However, it was determined that TNPM-315 (45.7%), TNPM-316 (57.3%), and TNPM-314 (61.7%) were susceptible. The disease intensity was highest in Nilavour local check variety (98.2%) and lowest in TNPM 230 (check variety) (19.9%).

Jain (2021) evaluated the thirty two finger millet cultivars against leaf blast (*Pyricularia grisea*), banded blight (*Rhizoctonia solani*) and leaf blight (*Drechslera nodulosa*) was studied under open field condition and the Average leaf blast severity, banded blight incidence and leaf blight incidence ranging from 2.2 to 7.0, Grade 15.8 to 37.1% and 22.0 to 75.0%, respectively were recorded. GPU 100 was found resistant to leaf blast. Whereas, 19 were moderately resistant and 12 were susceptible. None of the cultivars examined were resistant to banded blight. However, 21 were moderately resistant and 11 were susceptible. Also, none of the cultivars were resistant to leaf blight. VR 1125 was moderately resistant, 22 were sensitive and 9 were very susceptible to blight. Cultivar VR 1125 showed several moderately resistant reactions to leaf spot, tapeworm. Eleven varieties namely PR 1643, PR 1506, PRS 38, IIMR-R 18-5538, IIMR-R 18-5725, RAUF 21, DPLN-2, DHFM 4-9, VR 1125, VL 376, PPR were moderate resistant.

Ramesh et al. (2021) conducted a study on the severity of leaf blight in browntop millet. Based on the morphological characterization, the blight was identified as *Bipolaris* spp. However, host range was restricted to browntop millet and was found to be non-pathogenic to the other six minor millets examined. Finally, the characterization of *B. setariae* causing leaf blight of millet in India was carried out.

Nagaraja et al. (2022) worked on a new high yielding as well as disease resistant against leaf blight foxtail millet (*Setaria italica*). A new variety named GPUF 3 were released by the ICAR-AICRP, from the University of Agriculture science, GKVK, Bengaluru, and this variety is moderately resistant to leaf blight and rust disease and it is rich in nutritional quantities as well as better grain yield as compare to check variety (SiA 3156).

Rawat et al. (2022) a field experiment was conducted to evaluate the effect of seed treatment, seed strengthening and soil application of value-added FYM on growth parameters, yield, yield promoting traits, sheath blight control and economics of millet. As measured by plant

growth parameters, T11 (FYM pre-colonized with *Trichoderma asperellum*, *Pseudomonas fluorescens*, *Bacillus subtilis*) was found to be the best for plant height, number of productive tillers per plant, and ear length 148.45 cm, 5.20, 4.06 and 18.62 cm, respectively Treatment T11 also performed best in terms of yield (22.67 q/ha) and disease control (100.00 percent disease control efficiency), followed by T8 (T8 (FYM pre-colonized with *Trichoderma asperellum*) with a yield of 21.88 q/ha ha and with disease control 96.00 percent over control. The highest cost-benefit was recorded in treatment T11 (1:2.47), followed by T8 (1:2.38). The results showed that soil application of *Trichoderma asperellum*, *Pseudomonas fluorescens* *Bacillus subtilis* (@ 5 kg pre-colonized FYM/plot) proved to be most effective and promising in improving morphophysiological growth, yield and economics. resistance to sheath blight caused by *Rhizoctonia solani*.

2.3 Morphological traits of seeds obtained from harvested barnyard millet germplasm.

Baryeh (2002) studied the physical and mechanical properties of millet and other grains and seeds. The millet's physical characteristics have been assessed in relation to its grain moisture content, which ranges from 5% to 22.5%. (db). The grain's length, width, thickness, and geometric diameter increased in this moisture range from 3.522 to 4.163 mm, 2.735 to 3.211 mm, 2.180 to 2.788 mm, and 2.759 to 3.340 mm, respectively; the grain's surface area, volume, and sphericity increased from 23.91 to 35.05mm², 8.2 to 14.65mm³, and 0.783 to 0.803 respectively; the 1000 seed mass, true density, angle parameters were also calculated.

Amgai et al. (2013) studied four hundred thirty-nine finger millet plants collected from different regions of the country during the millet growing season of 2009 and 2010. Seed surface, shape, and color were morphological characteristics evaluated using two 1.5 m enlarged models. long rows and the distance between them are 20 cm. The seed colours observed were GPU- 8, Kabre, Kodo 1 as light brown, Dalle as copper brown and Okhale as purplish brown. The seed shape types observed were GPU- 8, Kabre, Kodo 1, Okhale round and Dalle ovoid. The seeds of Dalle, GPU- 8, Kabre and Kodo 1 had a smooth surface, while Okhale had a bumpy surface. This variation may be useful in generating finger millet varieties with broad adaptability and niche specificity.

Kumar et al. (2019) evaluated the 92 finger millet accessions for qualitative

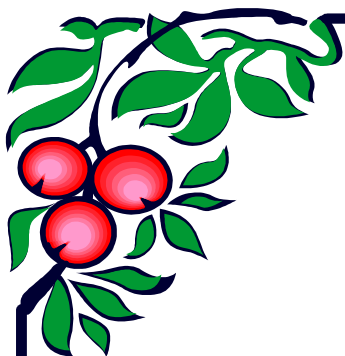
morphological descriptors. According to DUS norms set by PPV&FR, observations were made for sixteen qualitative traits on a visual basis at various phases of development. A majority of the 92 accessions showed erect growth (50%). The majority of germplasm entries had nonbranched fingers (88.40%) and many whorls (91.30%), whereas the majority of branching fingers (63.04%) were at the position of the thumb. The majority of genotypes' seeds are brown hue (55.43%), a round shape (42.39%), a rough surface (52.17%), an un persistent pericarp (76.08%), and a shattering tendency (60.87%) in addition to the other characteristics listed above.

Patel et al. (2019) conducted a field study to evaluate 20 accessions of finger millet. Based on morphology, plant growth, and yield-contributing characteristics, data was gathered. Among the examined accessions, traits including an erect growth habit (80%), a semi-compact ear (60%) and partially contained seeds by glumes (60%) were found to be predominate. The findings showed that the examined landraces varied in terms of finger number (6 to 14), finger length (7 to 16 cm), and maturation days (85 to 117), as well as in terms of seed form and colour. All of the traits were highly significant among the accessions, according to the analysis of variance.

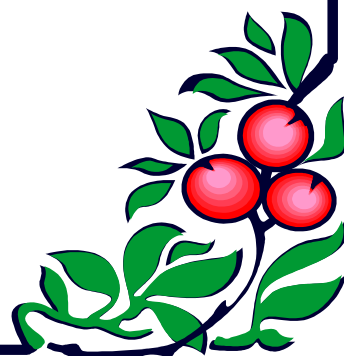
Nilavarasi et al. (2020) worked on 11 genotypes of barnyard millet crop to determine the genotypes' primary diagnostic traits. There was a total of 12 morphological characters were observed. Out of the 12 morphological characters, three quantitative characters like plant height (cm), 50% of flowering (days), and panicle length (cm) as well as nine qualitative traits like pigmentation, inflorescence colour, inflorescence shape, stamen colour, stigma colour, panicle compactness, spikelet arrangement, lower raceme shape, and seed color were studied. Morphological characters such as seed color was examined and 7 genotypes (MDU 1, ACM 16 343, ACM 16 353, TNEF 317, TNEF 318, IEC 356 and PRJ 1) were found to be grey in color while three genotypes (CO (KV)) 2, M 38 and IEC 350) were light grey. From this experiment, we can obtain information on differentiation between different field barnyard millet genotypes using these variations in morphological characteristics and simultaneously perform DUS tests on different field barnyard millet germplasm. Therefore, a detailed morphological description of plants and seeds must be prepared.

Mishra et al. (2022) analysed, eight distinct varieties of barnyard millet in the field for morphological characteristics such seed colour and shape. Various seed colours were known,

including Grey and straw-white (BYM-1), brownish grey (BYM-2), straw-white (BYM-3), grey and straw-white (BYM-4), straw-white (BYM-5), grey and straw-white (BYM-6), grey and straw-white (BYM-7), and BYM-8 (Light grey). There are several seed morphological traits that were identified as concave, including BYM-1, BYM-2, BYM-3, BYM-4, BYM-5, BYM-6, BYM-7, and BYM-8. Analysis of the qualitative data concluded that there was a high degree of variability between barnyard millet crop due to the various characteristics of the lines. Due to the difference in genetic composition, this research can be used for species identification under field conditions, selection, seed quality control, seed production, propagation and seed certification. Differences between several millet cultivars allowed these differences in morphological characteristics



MATERIALS AND METHODS



The present investigation entitled “**Evaluation of barnyard millet germplasm for morphometric characterization and screening against important endemic diseases in mid-hills of Uttarakhand**” was carried out during *Kharif -2022* at Plant Pathology Block (B-Block), College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand. The details of experimental materials used and procedures followed during the course of investigations are presented in this chapter under the following headings.

3.1. Site of Experiment

3.1.1. Location

The experimental site Plant Pathology Block at College of Forestry, Ranichauri is located 10 km from Chamba town at about 2100 m above mean sea level between 30°15'N and 78°30'E in the mid-zone of Uttarakhand, India. Field evaluations of genotypes are carried out in the experimental section of the Plant Pathology Department. Few morphological observations and evaluation of the harvested seeds were assessed in the Laboratory of Plant Pathology Department, College of Forestry, Ranichauri.

3.1.2. Climate and weather

Ranichauri campus experiences a humid and temperate type of climate with chilled winters. The mean monthly minimum and maximum temperature during crop growing season (May, 2022 to November, 2022) varied between 4.33 ° C to 26.1° C, respectively, (**Appendix I**). The average annual rainfall of the experimental site was recorded 36.74 cm (Source: Department of Agrometeorology, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand).

3.1.3. Soil

The soil of Plant Pathology Block is brownish black with silty clay loam in texture, having slightly acidic with pH 5.3 to 5.9. The bulk density of the soil varied from 1.15 to 1.31 mg/m³ and electrical conductivity ranged from 0.007 to 0.086 dS/m² across the field.

3.2. Experimental Materials

The experimental materials for the present investigation comprised of 54 genotypes of barnyard millet including two check varieties i.e. PRJ- (BM-20) and VL-207 (BM-21). The seed material for present investigation was obtained from the ICAR funded project entitled “AICRP on Small Millets” running at Ranichauri Centre, College of Forestry, Ranichauri. An over view of experimental field is depicted in **Plate-1**

3.3. Experimental Details

Fifty-four germplasm were taken as treatments in the proposed study. The different germplasm used in the present study are depicted in **Table 3.1**.

Table 3.1. List of barnyard millet germplasm used in the experiment

SI. No.	Germplasm	SI. No.	Germplasm	SI. No.	Germplasm
1.	BM-1	19.	BM-19	37.	BM-37
2.	BM-2	20.	BM-20	38.	BM-38
3.	BM-3	21.	BM-21	39.	BM-39
4.	BM-4	22.	BM-22	40.	BM-40
5.	BM-5	23.	BM-23	41.	BM-41
6.	BM-6	24.	BM-24	42.	BM-42
7.	BM-7	25.	BM-25	43.	BM-43
8.	BM-8	26.	BM-26	44.	BM-44
9.	BM-9	27.	BM-27	45.	BM-45
10.	BM-10	28.	BM-28	46.	BM-46
11.	BM-11	29.	BM-29	47.	BM-47
12.	BM-12	30.	BM-30	48.	BM-48
13.	BM-13	31.	BM-31	49.	BM-49
14.	BM-14	32.	BM-32	50.	BM-50
15.	BM-15	33.	BM-33	51.	BM-51
16.	BM-16	34.	BM-34	52.	BM-52
17.	BM-17	35.	BM-35	53.	BM-53
18.	BM-18	36.	BM-36	54.	BM-54



**Plate-1 An overview of field experimental trail of 54 barnyardmillet
germplasm
(Date of sowing- 28-05-2022)**

3.3.1. Experimental design and layout

The experiment was laid out in Randomized Block Design (RBD) during *kharif* season under rainfed conditions. Each of the entry was sown in two continuous rows of 2 meter in length manually in three replications. The sowing was done in second fortnight of May, 2022. The detail of experimental layout is given in **Table 3.2** and **Fig. 1** and **Fig. 2**:

Table 3.2 The details of experimental layout

Crop	Barnyard millet
Design	Randomized block design (RBD)
Replications	3
Number of accessions	54 (Including two check)
Row to Row spacing	22.5 cm
Plant to Plant spacing	10 cm
Plot dimensions (For 1 entry per replication)	0.45 m x 2 m (0.9 m ²)
Recommended dose of fertilizers	5-10 tonnes FYM and 40:20:20 (NPK) per hectare
Date of sowing	28-05-2022

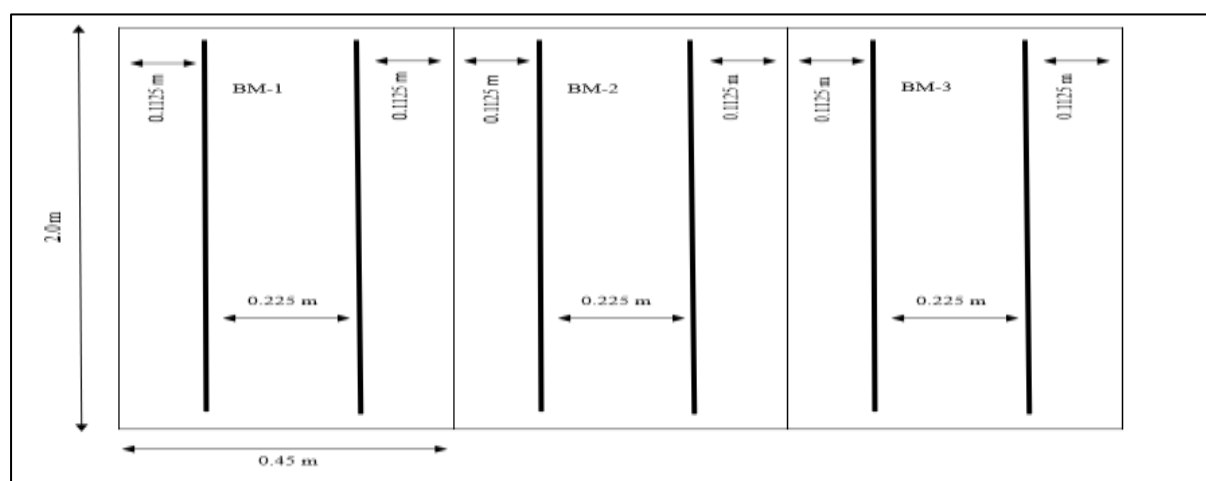


Fig. 1 Detailed layout of each entry in field experiment

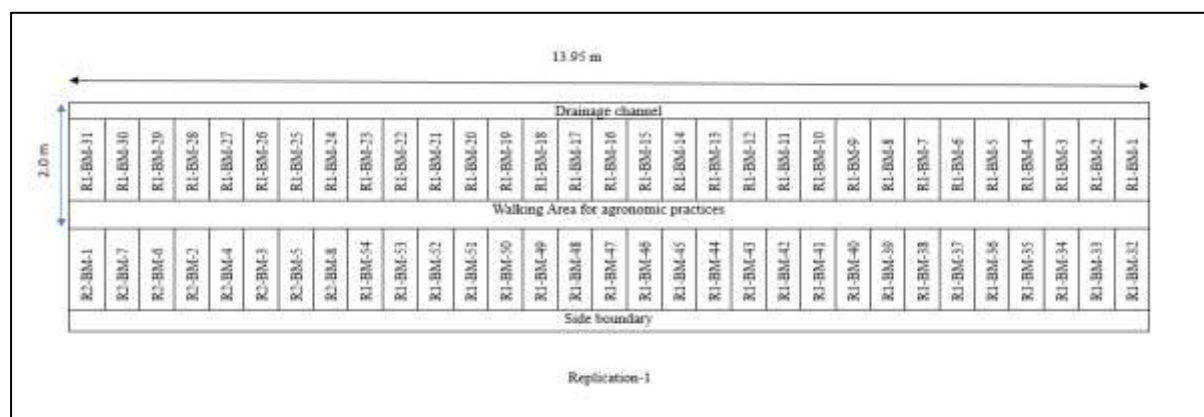


Fig. 2 (a)

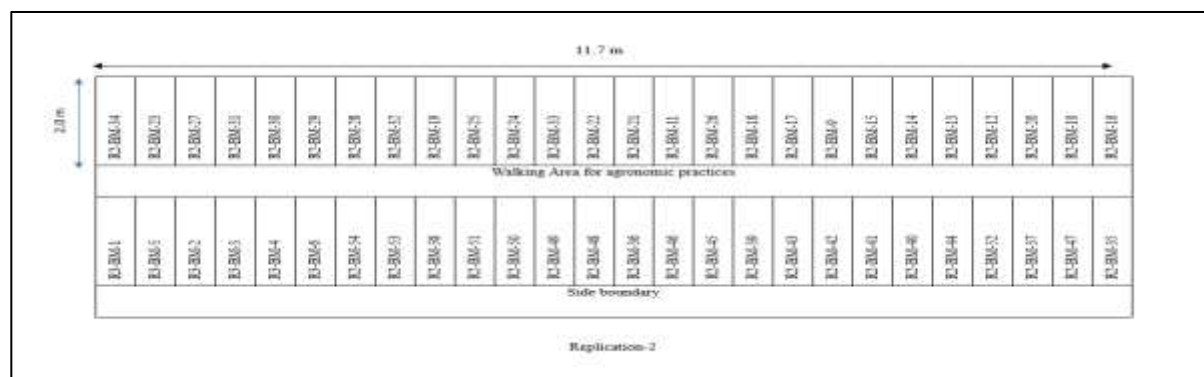


Fig. 2 (b)

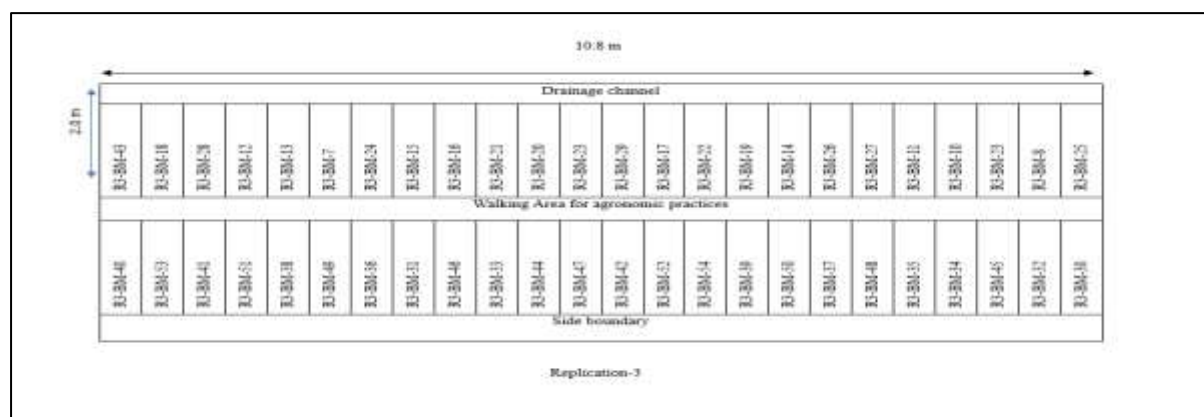


Fig. 2 (c)

Fig. 2 An overview of experimental layout of each replication

3.4. Observations Recorded

3.4.1. Field observations

Filed observations were recorded for various growth and yield related characters during the growth period of the barnyard millet as shown in **Plate-2**.

3.4.1.1. Plant height (cm)

Plant height was recorded at the time of maturity stage. For this, the height of five randomly selected plants was measured with measuring tape from the ground level to the top most panicle. The average was expressed as plant height in cm.

3.4.1.2. Days to maturity

Number of days to maturity was observed by recording the days taken by crop from sowing to maturity.

3.4.1.3. Days to 50% flowering

The number of days required to initiate 50% flowering was recorded for each genotype.

3.4.1.4. Number of productive tillers

The total number of basal tillers in each plant was counted by randomly selected five plants in each genotype in all three replications at flowering time and their mean value was recorded.

3.4.1.5. Number of basal tillers

The number of tillers emerging from the base of the plants was counted in five randomly selected plants of each germplasm and their mean value was calculated.

3.4.1.6. Panicle length (cm)

The panicle length was recorded on five randomly selected plants from ear head tip to ear head joint. The average of five ear head was calculated and recorded as panicle length in centimetres.

3.4.1.7. Panicle compactness

Panicle compactness was visually observed in which two characteristic features of compactness was found, one is compact and other is open. No statistical analysis was carried out on panicle compactness.

3.4.1.8. Inflorescence colour

Inflorescence colour was visually observed in which three distinct colours of inflorescence were observed viz., green, light purple and dark purple. No statistical analysis was carried out on inflorescence colour.

3.4.1.9. Inflorescence shape

Inflorescence shape was visually observed in which two diverse shapes of inflorescence were observed viz., cylindrical and globose/elliptical.

3.4.1.10. Panicle weight (g)

Weight of five randomly selected panicles were recorded for each entry of three replications at harvest stage and then averaged to get the mean panicle weight.

3.4.1.11. Biological yield (kg/ha)

All the harvested seeds were selected separately from each entry and then sun dried for 4-5 days and weighed using electronic balance and their values were converted in kg/ha.

3.4.1.12. Harvest index (%)

Harvest index was calculated as follow:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.4.1.13. Fodder yield (kg/ha)

Fodder yield was measured by subtracting the grain yield from biological yield of each entry and values were recorded and then converted in kg/ha.



A



B



C



D

A- Visual observation for disease incidence; B- Counting the number of basal tillers C- Crop at maturity; D- Harvesting the matured barnyard millet germplasm for grain yield

Plate-2 Recording of morphometric observations under field conditions

3.4.1.14. Grain yield per plot (kg)

It is an average yield of grains per entry of three replications of each entry and then their mean values were converted in kg/ha.

3.4.1.15. 1000 seed weight (g)

After drying the seeds up to the optimum moisture level, 1000 seeds were counted from each entry and their weight was measured on electronic balance.

3.4.1.16. Severity of grain and head smut

Severity of grain and head smut was rated on 1-9 score. The following scale was used for scoring grain and head smut diseases in barnyard millet (Proceedings of Annual Group Meeting of AICRP on Small Millets, 2017).

SCORE	DESCRIPTION	DISEASE REACTION
1	Less than 1% grains in a panicle affected	Highly resistant (HR)
2	1-5% grains in a panicle affected	Resistant (R)
3	6-10 grains in a panicle affected	Resistant (R)
4	11-20% grains in a panicle affected	Moderately resistant (MR)
5	21-30% grains in a panicle affected	Moderately resistant (MR)
6	31-40% grains in a panicle affected	Susceptible (S)
7	41-50% grains in a panicle affected	Susceptible (S)
8	51-75% grains in a panicle affected	Highly susceptible (HS)
9	More than 75% grains in a panicle affected	Highly susceptible (HS)

3.4.1.17. Severity of leaf blight (Rating)

Severity of leaf blight was rated on 1-9 score. Following scale was used for scoring leaf blight disease in barnyard millet (Proceeding of Annual Meeting of AICRP on Small Millets 2017).

SCORE	DESCRIPTION	DISEASE REACTION
1	Less than 1% leaf area affected	Highly resistant (HR)
2	1-5% leaf area affected	Resistant (R)
3	6-10% leaf area affected	Resistant (R)
4	11- 20% leaf area affected	Moderately resistant (MR)
5	21-30% leaf area affected	Moderately resistant (MR)
6	31-40% leaf area affected	Susceptible (S)
7	41-50% leaf area affected	Susceptible (S)
8	51-75% leaf area affected	Highly susceptible (HS)
9	More than 75% leaf area affected	Highly susceptible (HS)

3.4.1.18. Severity of sheath blight (Rating)

The severity of the banded blight was rated on 1-9 scale. The following scale was used for scoring banded blight disease in barnyard millet (**Proceeding of Annual Meeting of AICRP on Small Millets, 2017**).

SCORE	DESCRIPTION	DISEASE REACTION
1	< 1% of plant area covered by the lesion.	Highly resistant (HR)
2	1-5% of plant area covered by the lesion.	Resistant (R)
3	6-10% of plant area covered by the lesion.	Resistant (R)
4	11- 20% of plant area covered by the lesion.	Moderately resistant (MR)
5	21-30% of plant area covered by the lesion.	Moderately resistant (MR)
6	31-40% of plant area covered by the lesion.	Susceptible (S)
7	41-50% of plant area covered by the lesion.	Susceptible (S)
8	51-75% of plant area covered by the lesion.	Highly susceptible (HS)
9	>75% of plant area covered by the lesion.	Highly susceptible (HS)

3.4.2. Morphological observations of harvested seeds

3.4.2.1. Seed coat colour

Seed coat colour was visually observed on group of 50 seeds and recorded from each barnyard millet accession. Based on the morphological observation of seeds, five different seed coat colours have been reported.

3.4.2.2. Seed surface

Seed surface was observed on group of 50 seeds by holding the seed between the two fingers and recorded as smooth and wrinkled. No statistical analysis was carried out on seed surface.

3.4.2.3. Seed shape

Seed shape was observed visually on group of 50 seeds of each accession and identified as ovoid and concave shape. No statistical analysis has been carried out.

3.4.2.4. Seed dimensions (mm)

Seed length and width was recorded at the time of harvesting. For this a group of 10 seeds from each accession were randomly selected and measured by using electronic digital vernier caliper scale, in which seeds are placed in external measuring jaws.

3.5. Statistical Analysis

The following statistical analysis was performed on the mean of the different observations in order to derive conclusions from the current research.

3.5.1. Analysis of variance (ANOVA)

The statistical analysis for the characters studied was done by the method recommended by Cochran and Cox (1992) for Randomized Block Design (RBD).

Source of variation	Degree of freedom	Sum of square	Mean sum of square	Variation ratio (F-value)
Replication (r)	(r-1)	SSr	$MSr = \frac{SSr}{(r-1)}$	$\frac{MSr}{MSe}$
Treatment (t)	(t-1)	SSt	$MSt = \frac{SSt}{(t-1)}$	$\frac{MSt}{MSe}$
Error	(r-1) (t-1)	SSe	$MSe = \frac{Se}{(r-1)(t-1)}$	
Total	r (t-1)			

The calculated 'F' values were computed with tabulated 'F' values wherever, value was found significant, Standard Error (SE), Critical Difference (CD) and Coefficient of Variation (CV) was calculated to find out the superiority of a treatment upon other.

$$SE(m) \pm = \sqrt{\frac{Me}{r}}$$

$$SE(d) \pm = \sqrt{\frac{2Me}{r}}$$

CD (0.05) = SE (d) x table value of t (0.05) at error degree of freedom.

Where:

SE (m) $\pm$ = Standard error of mean difference

CD (0.05) = Critical difference at 5% level of significance.

All the characters which showed significant differences among genotypes were further subjected to analysis for the following parameters.

3.6. Genetic Variability

The phenotypic and genotypic variance component and genotypic and phenotypic coefficient of variation were mentioned below.

Error mean square (MSe) = V_e

3.6.1. Genotypic variance (V_g) = $\frac{MSg-Mse}{r}$

Where: - MSg: mean square genotype, MSe: Error mean square and r: replication.

3.6.2. Phenotypic variance (V_p) = $V_g + V_e$

$$GCV\% = \frac{\sqrt{V_g}}{\bar{x}} \times 100$$

$$PCV\% = \frac{\sqrt{V_p}}{\bar{x}} \times 100$$

3.6.3. Heritability (h^2)

$$\text{Heritability } (h^2) = \frac{V_g}{V_p} \times 100$$

Where: h^2 = heritability, V_p = Phenotypic variance, V_g = Genotypic variance.

3.6.4. Genetic advance as percent of mean

$$GAM = \frac{GA}{\bar{x}} \times 100 \quad \text{Where: GAM: Genetic advance as percent of mean, GA: Genetic$$

advance and $\bar{x}$ = Grand mean.

3.6.5. Coefficient of variation

Variability for different characters was estimated as suggested by the coefficient of variability at genotypic (GCV), phenotypic (PCV), and environmental (ECV) levels were estimated as follows: (Burton and Devane, 1953).

a) Phenotypic Coefficient of Variation (PCV)

$$PCV (\%) = \frac{\sqrt{\text{Phenotypic variance } (V_p)}}{\text{General mean of population } (GM)} \times 100$$

b) Genotypic Coefficient of Variation (GCV)

$$GCV (\%) = \frac{\sqrt{\text{Genotypic variance } (V_g)}}{\text{General mean of population } (GM)} \times 100$$

c) Environmental Coefficient of Variation (ECV)

$$ECV (\%) = \frac{\sqrt{\text{Environmental variance } (V_e)}}{\text{General mean of population } (GM)} \times 100$$

Where: $V_e = M_e$, $V_g = \frac{MSt - MSe}{r}$ and $V_p = V_g + V_e$

3.6.6. Heritability

Heritability was calculated by variance component method, as ratio of genotypic variance to phenotypic variance and expressed in percentage (**Allard, 1960**).

$$\text{Heritability } (h^2) = \frac{\text{Genotypic variance } (V_g)}{\text{Phenotypic variance } (V_p)} \times 100$$

3.6.7. Genetic Advance

The expected genetic advance resulting from selection of five percent superior individuals were worked out as given by **Burton and Devane (1953)** and **Johnson et al. (1955)**.

$$\text{Genetic advance} = h^2 \times \sqrt{V_p} \times K$$

Where, h^2 = Heritability in broad sense, $\sqrt{V_p}$ = Phenotypic standard deviation and K = Selection differential at 5% selection intensity

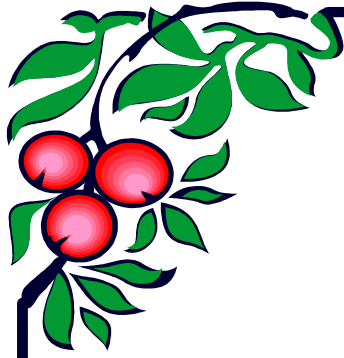
The value of $K = 2.06$ (**Allard, 1960**).

For categorizing the magnitude of different parameters, the limits used are given below;

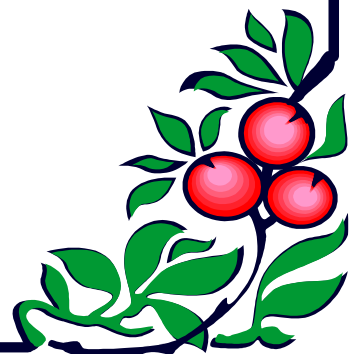
PCV and GCV	> 20%	-	High
	10-20 %	-	Moderate
	<1-10 %	-	Low

Heritability (h^2)	> 60%	-	High
	30-60 %	-	Moderate
	<1-30%	-	Low

$$\text{Mean } (\bar{X}) = \frac{\text{Sum of observations}}{\text{total no of observations}}$$



EXPERIMENTAL RESULTS



The present investigation entitled “**Evaluation of barnyard millet germplasm for morpho-metric characterization and screening against important endemic diseases in mid-hills of Uttarakhand**” was carried out on 54 genotypes of barnyard millet at Plant Pathology Block, V.C.S.G. Uttarakhand University of Horticulture and Forestry, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand. The results obtained from various field observations and morphological observations of seed parameters are as given below:

4.1. Morphological appearance of genotypes

4.2. Mean performance of genotypes

4.2.1 Field parameters

4.3. Disease assessment (field conditions)

4.4. Seed attributing traits

4.5. Analysis of variance for morphometric traits

4.6 Genetic components

4.1. Morphological appearance of genotypes

The results of qualitative traits such as inflorescence colour shape and panicle compactness (**Table 4.1**) scored for different genotypes are presented below:

4.1.1. Inflorescence colour

The hue of the inflorescence of barnyard millet germplasm was visually assessed and noticed as green, dark purple, and light purple as depicted in **Plate-3**. Out of 54 distinct barnyard millet germplasm, 51 germplasm showed green inflorescence colour, accounting for 94.44 percent, whereas one germplasm had dark purple inflorescence, accounting for 01.85 percent and inflorescence of two germplasm have been characterized as light purple, accounting for 03.70 percent.

4.1.2. Inflorescence shape

The shape of the inflorescence was visually perceived and recorded as cylindrical and globose/elliptical (**Plate-4**). Out of 54 barnyard millet germplasm, 49 germplasm showed cylindrical shape which accounts for 90.74 percent and 5 germplasm have assessed as globose-elliptical shape which accounts for 9.25 percent.

4.1.3. Panicle compactness

On visual examination of inflorescence, it revealed that panicle looked either open or compact as presented in **Plate-4**. Out of total studied germplasm, 53 were having a compact panicle shape except one germplasm (BM-52) which showed open panicle and were accounting for 98.14 percent and 1.85 percent respectively.

4.2. Mean performance of genotypes

4.2.1. Field parameters (quantitative traits)

The mean performances of 54 genotypes for various field parameters (quantitative traits) studied are given in **Table 4.2**. The results for the morphometric characterization of the parameters related to barnyard millet crop are concise as under.

4.2.1.1. Days to 50% flowering

A thorough examination of data regarding days to 50% flowering ranged from 63.67 days to 88.00 days with the general mean of 76.11. The five best genotypes for early days to 50% flowering were BM-20 (63.67 days), BM-1 (65.33 days), BM-2 (67.00 days), BM-48 (66.67%) and BM-41 (67.67 %).

4.2.1.2. Days to maturity

For the trait of days to maturity, the mean values varied in respect to genotypes and the difference in duration was ranged from 135.00 days to 153.00 days with a general mean of 144.10 days. Majority of genotypes showed significant differences for days to maturity. The best five genotypes for early maturity were BM-20 (135.00 days), BM-1 (136.00 days), BM-18 (136.00 days), BM-24 (136.67 days) and BM-19 with 137.67 days.

4.2.1.3. Plant height (cm)

For the character plant height, the mean value varied from 124.67 cm to 157.00 cm where the general mean was 139.14 cm. The best five genotypes for shorter stature were BM-44 (124.67 cm), BM-39 (125.00 cm), BM-38 (126.00 cm), BM-40 (126.33 cm) and BM-54 (128.00 cm) whereas some of the best genotypes for tall stature were BM-36 (157.00 cm), BM-21 (148.00 cm), BM-31 (148.00 cm), BM-2, BM-26 and BM-48 with height of 146.00 cm each.

4.2.1.4. Number of basal tillers

The mean value for the number of basal tillers ranged from 5.50 to 8.00. The minimum numbers of basal tillers were observed in BM-15 and BM-19 with the mean value of 5.50 each whereas, the maximum number of basal tillers was found in BM-1 with the mean value of 8.00 followed by BM-34 (7.83) and BM-22 (7.67).

4.2.1.5. Number of productive tillers

Mean values of the number of productive tillers were ranged from 1.40 to 3.17. The highest number of productive tillers was recorded in BM-1 (3.17) followed by BM-34 (3.07) while, the lowest number of productive tillers was recorded in BM-29 (1.40) followed by BM-20, BM-32 and BM-38 with 1.50 number of productive tillers each.

4.2.1.6. Panicle length (cm)

Data regarding panicle length reported a range of 10.10 cm to 24.20 cm with an overall mean value of 15.9 cm. It is apparent from the data given in **Table 4.2** that the maximum panicle length was recorded in genotype BM-40 (24.20 cm) followed by BM-1 (23.40 cm) and BM-18 (23.20 cm) however, the minimum panicle length was recorded in BM-44 (10.10) followed by BM-8 with 10.17 cm length.

4.2.1.7. Panicle weight (g)

The evaluation of panicle weight of barnyard millet recorded a mean value ranges

between 14.00 g to 26.67 g with the general mean of 19.00. The best five genotypes for highest panicle weight were recorded in BM-1 with 26.67 g followed by BM-34 (26.00), BM-27 (25.00), BM-3 (24.33) and BM-11 (24.33).

4.2.1.8. Grain yield (Kg/ha)

For the parameter grain yield, the genotype BM-1 (1925.93 Kg/ha) followed by BM-34 (1901.23 Kg/ha), BM-11 (1888.89 Kg/ha) and BM-16 (1851.85 Kg/ha) recorded the highest mean value, whereas, the lowest values were observed in genotype BM-48 (1259.26 Kg/ha) followed by BM-46 (1277.78 Kg/ha) and BM-8 (1296.30 Kg/ha) with a general mean of 1604.14.

4.2.1.9. Fodder yield (Kg/ha)

A thorough examination of data for fodder yield showed the higher mean value in the genotype BM-1 (5777.78 Kg/ha) followed by BM-34 (5333.33 Kg/ha), BM-27 (5151.85 Kg/ha) and BM-44 (5137.04 Kg/ha) while, minimum values were reported in genotype BM-29 (3444.44 Kg/ha) followed by BM-23 (3492.59 Kg/ha) with a general mean of 4164.47.

4.2.1.10. 1000 Seed weight (g)

A critical analysis of data for 1000 seed weight presented in **Table 4.2** showed that the genotypes showing highest mean value was BM-1 (3.85 g) followed by BM-34 (3.80 g) whereas the minimum 1000 seed weight was observed in BM-25 (2.12 g) followed by BM-27 (2.21 g). The best five genotypes for 1000 seed weight were BM-1 (3.85 g), BM-34 (3.80 g), BM-22 (3.78 g), BM-18 (3.75 g) and BM-20 (3.75 g).

4.2.1.11. Biological yield (Kg/ha)

The mean value for character variability in biological yield ranged from 4907.41 to 7029.63 Kg/ha. A close review of data indicates that the genotype BM-33 with 4907.41 Kg/ha recorded the lowest biological yield followed by BM-23 (4937.04 Kg/ha), whereas, the highest biological yield was recorded in BM-1 (7029.63 Kg/ha) followed by BM-34 (6970.37 Kg/ha) and BM-46 (6888.89 Kg/ha). All the genotypes showed a significant difference for the biological

yield of barnyard millet.

4.2.1.12. Harvest index (%)

A critical analysis of data presented in **Table 4.2** revealed that the mean values for harvest index showed a range between 19.38 % to 34.04 % and the general mean was reported to be 27.31 %. The highest harvest index was observed to be in genotype BM-29 (34.04 %) followed by BM-19 (33.98 %) and BM-18 (33.45 %) whereas, minimum harvest index was recorded in BM-46 (19.38 %) followed by BM-44 (21.91 %).

Table 4.1: Evaluation of barnyard millet germplasm for inflorescence colour, inflorescence shape and panicle compactness

Entry no.	Inflorescence colour	Inflorescence shape	Panicle compactness
BM-1	Light purple	Cylindrical	Compact
BM-2	Green	Cylindrical	Compact
BM-3	Green	Cylindrical	Compact
BM-4	Green	Cylindrical	Compact
BM-5	Green	Cylindrical	Compact
BM-6	Green	Cylindrical	Compact
BM-7	Green	Cylindrical	Compact
BM-8	Green	Cylindrical	Compact
BM-9	Green	Cylindrical	Compact
BM-10	Green	Cylindrical	Compact
BM-11	Green	Cylindrical	Compact
BM-12	Green	Cylindrical	Compact
BM-13	Green	Cylindrical	Compact
BM-14	Green	Cylindrical	Compact
BM-15	Green	Cylindrical	Compact
BM-16	Green	Cylindrical	Compact
BM-17	Green	Cylindrical	Compact
BM-18	Green	Cylindrical	Compact
BM-19	Green	Cylindrical	Compact
BM-20	Green	Cylindrical	Compact
BM-21	Green	Globose/elliptical	Compact
BM-22	Green	Cylindrical	Compact
BM-23	Green	Globose/elliptical	Compact
BM-24	Green	Globose/elliptical	Compact
BM-25	Green	Globose/elliptical	Compact

BM-26	Green	Cylindrical	Compact
BM-27	Green	Cylindrical	Compact
BM-28	Green	Cylindrical	Compact
BM-29	Green	Cylindrical	Compact
BM-30	Green	Cylindrical	Compact
BM-31	Green	Cylindrical	Compact
BM-32	Green	Cylindrical	Compact
BM-33	Green	Cylindrical	Compact
BM-34	Green	Cylindrical	Compact
BM-35	Green	Cylindrical	Compact
BM-36	Dark Pink	Cylindrical	Compact
BM-37	Green	Cylindrical	Compact
BM-38	Green	Cylindrical	Compact
BM-39	Green	Cylindrical	Compact
BM-40	Green	Cylindrical	Compact
BM-41	Green	Cylindrical	Compact
BM-42	Green	Cylindrical	Compact
BM-43	Green	Cylindrical	Compact
BM-44	Green	Cylindrical	Compact
BM-45	Green	Cylindrical	Compact
BM-46	Green	Cylindrical	Compact
BM-47	Green	Cylindrical	Compact
BM-48	Green	Cylindrical	Compact
BM-49	Green	Cylindrical	Compact
BM-50	Green	Cylindrical	Compact
BM-51	Green	Cylindrical	Compact
BM-52	Green	Globose/elliptical	Open
BM-53	Light purple	Cylindrical	Compact
BM-54	Green	Cylindrical	Compact

Table 4.2: Evaluation of barnyard millet germplasm for growth and yield related parameters

Entry No.	Days to 50% Flowering	Days to Maturity	Plant height (cm)	Number of Basal tillers	Number of Productive tillers	Panicle length (cm)	Panicle Weight (g)	Grain Yield (kg/ha)	Fodder Yield (kg/ha)	1000 Seed Weight (g)	Biological Yield (kg/ha)	Harvest Index (%)
BM-1	65.33	136.00	135.00	8.00	3.17	23.40	26.67	1925.93	5777.78	3.85	7029.63	24.99
BM-2	67.00	145.33	146.00	6.00	2.00	16.43	22.67	1666.67	3733.33	3.41	5400.00	30.83
BM-3	83.00	149.33	145.67	6.00	3.00	19.23	24.33	1722.22	4200.00	3.32	5922.22	29.06
BM-4	73.00	140.00	144.67	5.67	2.00	15.80	24.00	1555.56	3733.33	2.30	5288.89	29.38
BM-5	73.00	141.00	145.00	6.00	2.00	17.03	22.00	1740.74	3814.81	2.50	5481.48	30.37
BM-6	76.00	148.00	138.00	6.50	2.50	16.60	21.67	1777.78	4118.52	2.64	5785.19	28.78
BM-7	77.00	148.00	128.00	6.17	2.50	11.23	17.67	1444.44	4111.11	3.25	5555.56	26.01
BM-8	76.00	142.00	127.00	6.33	2.00	10.17	16.33	1296.30	4066.67	3.18	5400.00	24.67
BM-9	84.00	148.00	143.67	6.00	1.67	10.37	15.67	1481.48	3844.44	3.33	5177.78	25.74
BM-10	85.00	150.00	143.67	7.00	3.00	11.13	15.33	1518.52	5111.11	2.50	6555.56	22.00
BM-11	75.00	140.00	145.33	7.50	3.00	20.03	24.33	1888.89	4622.22	3.25	6511.11	29.02
BM-12	74.00	142.00	135.33	6.33	2.00	11.10	23.00	1629.63	4111.11	3.45	5666.67	27.42
BM-13	73.00	139.00	133.00	7.00	3.00	11.80	16.33	1703.70	4333.33	3.47	5777.78	24.95
BM-14	73.00	141.00	136.33	6.00	2.00	12.30	15.67	1814.81	3844.44	3.10	5400.00	28.79
BM-15	75.00	142.00	136.00	5.50	2.00	12.10	15.33	1592.59	3622.22	3.26	5177.78	30.02
BM-16	75.67	147.00	144.00	7.00	3.00	22.80	22.00	1851.85	4111.11	3.12	6000.00	31.47
BM-17	78.00	143.00	145.00	6.83	3.00	18.40	17.67	1685.19	4333.33	2.90	6000.00	27.79
BM-18	68.00	136.00	142.33	6.00	1.67	23.20	23.00	1740.74	3755.56	3.75	5644.44	33.45
BM-19	74.00	137.67	135.00	5.50	2.00	22.00	24.00	1666.67	3670.37	3.26	5559.26	33.98
BM-20	63.67	135.00	142.33	6.33	1.50	20.80	24.00	1777.78	4029.63	3.75	5807.41	30.59
BM-21	76.00	148.67	148.00	6.00	1.67	18.03	18.67	1666.67	3825.93	2.60	5492.59	30.30
BM-22	73.00	142.67	142.33	7.67	3.00	17.23	19.33	1555.56	5062.96	3.78	6618.52	23.49
BM-23	83.00	150.00	136.33	6.00	2.00	10.23	16.67	1444.44	3492.59	2.80	4937.04	29.19
BM-24	75.67	136.67	143.67	6.00	2.00	14.20	16.00	1555.56	3818.52	2.63	5374.07	28.91
BM-25	72.00	147.33	136.33	6.00	1.67	15.33	22.00	1666.67	4025.93	2.12	5692.59	29.27
BM-26	87.00	148.00	146.00	6.50	1.83	15.60	20.67	1555.56	4222.22	2.56	5777.78	26.91
BM-27	88.00	153.00	135.67	7.50	3.00	16.13	25.00	1481.48	5151.85	2.21	6707.41	23.17
BM-28	72.00	141.00	136.67	6.50	2.00	10.60	16.00	1444.44	3770.37	3.14	5214.81	27.67
BM-29	72.00	143.67	145.00	6.00	1.40	20.10	23.33	1777.78	3444.44	3.30	5222.22	34.04
BM-30	74.00	142.33	145.67	5.67	2.00	16.40	21.00	1666.67	4044.44	2.90	5711.11	29.17
BM-31	71.67	149.33	148.00	6.50	2.00	18.10	16.67	1555.56	4559.26	2.47	6114.81	25.41

BM-32	79.00	151.33	144.33	6.50	1.50	16.20	22.00	1666.67	3911.11	2.89	5577.78	29.86
BM-33	86.67	152.00	143.67	6.00	2.00	11.30	20.00	1518.52	3574.07	3.43	4907.41	27.17
BM-34	74.00	141.33	135.33	7.83	3.07	19.17	26.00	1901.23	5333.33	3.80	6970.37	26.15
BM-35	81.67	141.67	136.00	7.50	3.00	17.10	17.67	1555.56	4688.89	3.57	6244.44	24.87
BM-36	76.00	142.00	157.00	6.17	1.67	18.30	17.00	1481.48	3814.81	2.80	5370.37	28.96
BM-37	68.67	139.67	143.33	7.00	3.00	17.40	18.00	1740.74	4207.41	2.77	5948.15	29.19
BM-38	76.67	144.00	126.00	6.00	1.50	18.60	20.67	1555.56	3585.19	2.64	5140.74	30.24
BM-39	83.00	141.67	125.00	6.00	2.33	19.20	17.00	1444.44	3881.48	3.14	5437.04	28.61
BM-40	85.67	142.33	126.33	6.50	2.50	24.20	17.00	1740.74	4229.63	3.40	6118.52	30.84
BM-41	67.67	143.00	134.67	6.17	2.00	10.50	15.00	1444.44	3911.11	3.11	5355.56	26.92
BM-42	79.00	142.67	133.33	6.00	2.00	18.77	16.00	1777.78	3966.67	3.63	5744.44	30.92
BM-43	74.00	141.00	137.00	6.67	3.00	19.70	17.00	1703.70	4437.04	3.52	6214.81	28.60
BM-44	76.67	149.00	124.67	7.50	3.00	10.10	18.00	1444.44	5137.04	3.40	6581.48	21.91
BM-45	75.00	144.67	136.33	7.50	3.00	11.70	18.00	1333.33	4125.93	2.81	5570.37	25.92
BM-46	76.00	146.00	144.00	7.50	3.00	10.80	16.00	1277.78	3748.15	2.75	6888.89	19.38
BM-47	75.00	143.00	133.00	7.50	3.00	10.20	18.00	1444.44	4774.07	3.20	6218.52	23.23
BM-48	66.67	138.33	146.00	6.50	2.00	10.40	14.00	1259.26	3703.70	3.33	5037.04	26.42
BM-49	70.67	146.00	136.33	6.50	2.00	14.90	18.00	1555.56	4077.78	3.58	5633.33	27.58
BM-50	73.00	144.00	142.67	7.33	3.00	16.30	15.00	1481.48	4333.33	3.63	5888.89	26.37
BM-51	86.00	148.67	145.00	7.50	3.00	11.20	17.33	1444.44	4685.19	3.71	6129.63	23.53
BM-52	86.67	150.33	144.33	6.50	3.00	19.23	15.67	1777.78	4588.89	2.88	6925.93	26.09
BM-53	82.33	148.00	136.33	6.00	2.00	16.87	16.33	1555.56	4081.48	3.13	5637.04	27.55
BM-54	77.00	147.67	128.00	6.50	1.83	18.50	15.00	1666.67	3907.41	3.41	5574.07	29.86
CD at 5%	1.819	2.053	4.788	0.878	0.868	1.107	3.876	278.175	181.380	0.04	347.131	2.296
CV (%)	1.476	0.881	2.126	8.296	23.01	4.297	12.51	10.697	2.687	1.212	3.713	3.779
SEM	0.649	0.733	1.708	0.313	0.310	0.394	1.380	99.070	64.597	0.014	123.629	0.117
SE (d)	0.918	1.036	2.415	0.443	0.438	0.558	1.952	140.106	91.354	0.02	174.838	0.165
General Mean	76.11	144.09	139.14	6.54	2.33	15.90	19.00	1604.14	4164.47	3.122	5767.01	27.31
Highest	88.00	153.00	157.00	8.00	3.17	24.20	26.67	1925.93	5777.78	3.85	7029.63	34.04
Lowest	63.67	135.00	124.67	5.50	1.40	10.10	14.00	1259.26	3444.44	2.12	4937.04	18.35



Light Purple



Green



Dark Purple

Plate-3 Variation in inflorescence colour of barnyard millet



Globose/elliptical & Open



Cylindrical & Compact

**Plate-4 Variation in inflorescence shape and panicle compactness of
barnyard millet germplasm**

4.3. Disease assessment (Field condition)

The disease assessment was visually observed and the results obtained are mentioned in **Table 4.3** and depicted in **Plate 5**

4.3.1. Grain smut (%)

The disease incidence for grain smut was recorded for each germplasm. During the study it was found that genotype BM-39 (35.10), BM-18 (45.13), BM-4 (45.17) and BM-24 (50.10) were found susceptible for grain smut with maximum disease incidence. The following germplasm viz. BM-48 (25.01), BM-33 (25.07), BM-15 (25.13), BM-19 (25.20), BM-25 (25.26) and BM-29 (25.40) were found moderately resistant. However, genotype BM-13 (5.00), BM-3 (5.10), BM-9 (10.03), BM-36 (10.07), BM-14 (10.10), BM-30 (10.13), BM-31 (10.17), BM-2 (10.27), BM-47 (10.23), BM-7 (10.33) and BM-49 (10.43) were found resistant and the remaining genotypes were reported to be highly resistant.

4.3.2. Sheath blight (PDI)

The disease rating for Sheath blight was recorded in all the germplasms used in experimental trial. For each germplasm, the prevalence of sheath blight was noted. In the study, it was discovered that the germplasm BM-46 (1.42), BM-45 (2.33), BM-51 (2.33), BM-47 (2.35), BM-52 (2.43), BM-10 (3.26), BM-22 (3.37), BM-27 (3.41), BM-35 (4.26), BM-44 (4.41), BM-16 (6.52), BM-17 (7.40), BM-50 (7.40) and BM-31 (9.11) were found resistant to sheath blight and the remaining genotypes were found moderately resistant to the disease.

4.3.3. Leaf blight (G)

From 54 barnyard millet germplasm, the incidence of leaf blight disease was recorded for each germplasm. A critical analysis of data for leaf blight revealed that all the germplasm

were found resistant to leaf blight. Mean value of percent disease incidence for leaf blight ranged in between 3.00 % to 8.00% with a general mean of 5.42%. Most of the germplasm were found to be statistically at par to each other with no significant differences.

4.3.4. Head smut (%)

Fifty-Four barnyard millet lines were screened against Head smut disease, out of which only two genotypes (BM-18 and BM-24) with 3.33% and 5.55% disease incidence respectively, were found resistant to head smut and the remaining genotypes were reported to be highly immune to head smut disease.

4.4. Seed attributing traits (harvested seeds)

Performance of 54 genotypes for various seed related morphological parameters studied are given in **Table 4.4** and phylogenetic tree (**Figure 3**). The results for the Seed morphometric characterization of the parameters related to barnyard millet crop are concise as follows. Pictorial representation of data recording for seed character is shown in **Plate-6**

4.4.1. Seed dimensions (mm)

The length of seed was measured using digital vernier caliper, a slight variation in reading was recorded which showed a range between 2.17 mm to 3.20 mm of the genotype. Similarly seed width was measured, but no significant difference was observed which recorded a range between 1.46 mm to 2.44 mm with the highest seed width in BM-1 (2.44) and the lowest seed width recorded in BM-31 (1.46).

4.4.2. Seed shape

The seeds were identified as being ovoid and concave after a detailed examination as mentioned in **Fig. 3** (phylogenetic tree). Out of 54 different barnyard millet germplasm, 42 germplasm had concave seeds, which account for 77.78 percent and the remaining 12 germplasm had ovoid seeds, which account for 22.22 percent.

4.4.3. Seed coat surface

The surface of seed coat was tested physically and assessed and recorded as smooth and rough. There were 54 different germplasm of barnyard millet of which 46 of them had rough seed coat surface, which accounts for 85.18 percent of the total, while 8 had smooth seed surfaces, which accounts for 14.81 percent. The detailed information related to seed coat surface is mentioned in **Fig. 3** (phylogenetic tree).

Table 4.3: Evaluation of barnyard millet germplasm for grain smut, sheath blight, leaf blight and head smut disease under open field conditions

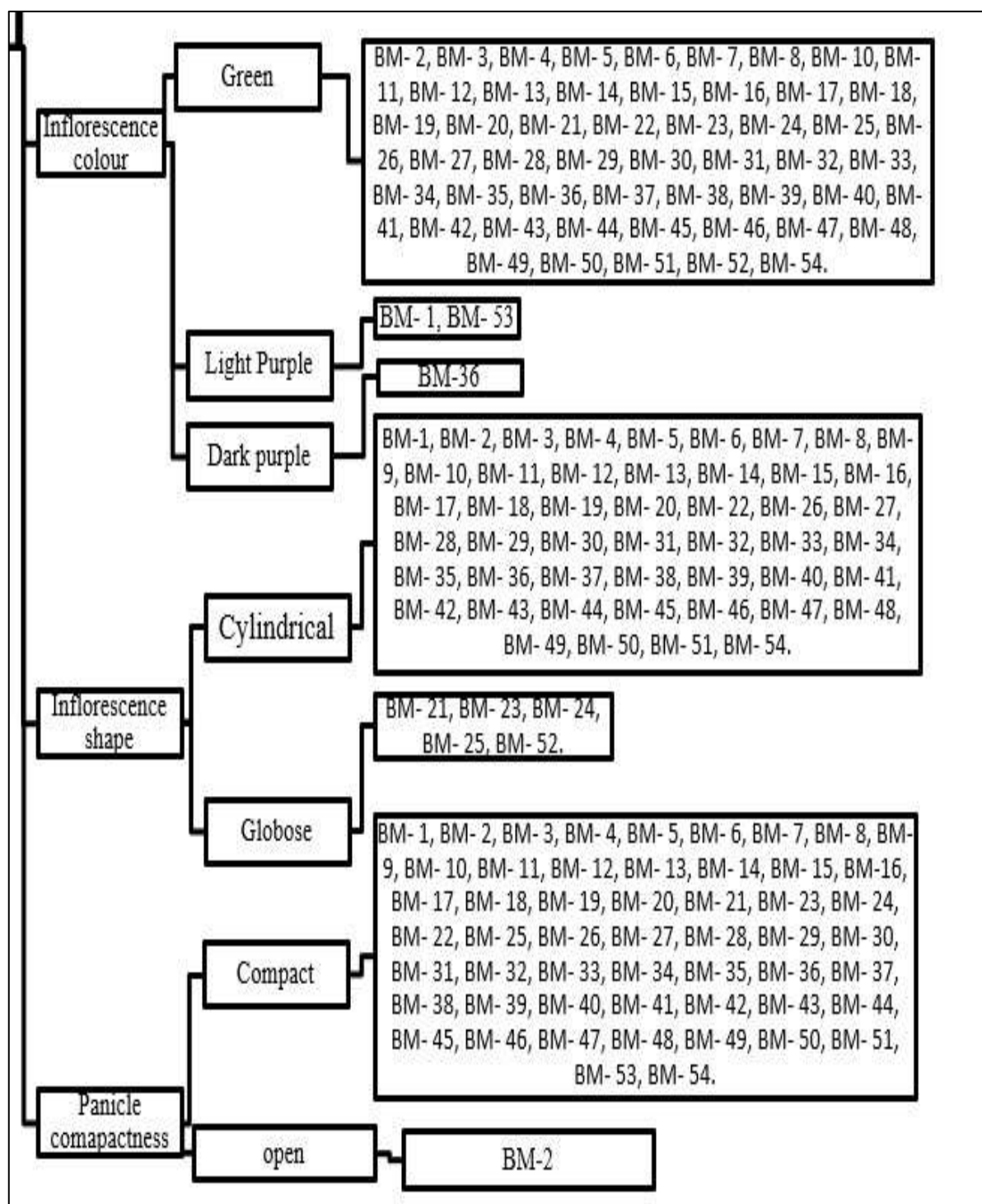
Entry no.	Grain smut (%)	Sheath blight (%)	Leaf blight (G)	Head smut (%)
BM-1	0.00 (HR)	17.19(MR)	6.00	0.00(HR)
BM-2	10.27 (R)	26.52(MR)	7.00	0.00(HR)
BM-3	5.10 (R)	15.46(MR)	5.00	0.00(HR)
BM-4	45.17(S)	27.07(MR)	8.00	0.00(HR)
BM-5	0.00(HR)	21.44(MR)	5.00	0.00(HR)
BM-6	0.00(HR)	13.40(MR)	5.00	0.00(HR)
BM-7	10.33(R)	19.11(MR)	6.00	0.00(HR)
BM-8	0.00(HR)	18.22(MR)	6.00	0.00(HR)
BM-9	10.03(R)	20.40(MR)	6.00	0.00(HR)
BM-10	0.00(HR)	3.26(R)	4.00	0.00(HR)
BM-11	0.00(HR)	2.55(R)	4.00	0.00(HR)
BM-12	0.00(HR)	16.48(MR)	6.00	0.00(HR)
BM-13	5.00(R)	14.44(MR)	5.00	0.00(HR)
BM-14	10.10(R)	24.16(MR)	7.00	0.00(HR)
BM-15	25.13(MR)	28.50(MR)	6.00	0.00(HR)
BM-16	0.00(HR)	6.52(R)	3.00	0.00(HR)
BM-17	0.00(HR)	7.40(R)	4.00	0.00(HR)
BM-18	45.13(S)	27.62(MR)	7.00	3.33(R)
BM-19	25.20(MR)	23.44(MR)	7.00	0.00(HR)
BM-20	0.00(HR)	16.62(MR)	6.00	0.00(HR)
BM-21	0.00(HR)	23.49(MR)	7.00	0.00(HR)
BM-22	0.00(HR)	3.37(R)	3.00	0.00(HR)
BM-23	0.00(HR)	22.42(MR)	6.00	0.00(HR)
BM-24	50.10(S)	27.51(MR)	5.00	5.55 (R)
BM-25	25.27(MR)	17.25(MR)	6.00	0.00(HR)
BM-26	0.00(HR)	11.27(MR)	6.00	0.00(HR)
BM-27	0.00(HR)	3.41(R)	4.00	0.00(HR)
BM-28	0.00(HR)	12.55(MR)	5.00	0.00(HR)
BM-29	25.40(MR)	24.30(MR)	7.00	0.00(HR)
BM-30	10.13(R)	17.55(MR)	6.00	0.00(HR)
BM-31	10.17(R)	9.11(R)	6.00	0.00(HR)

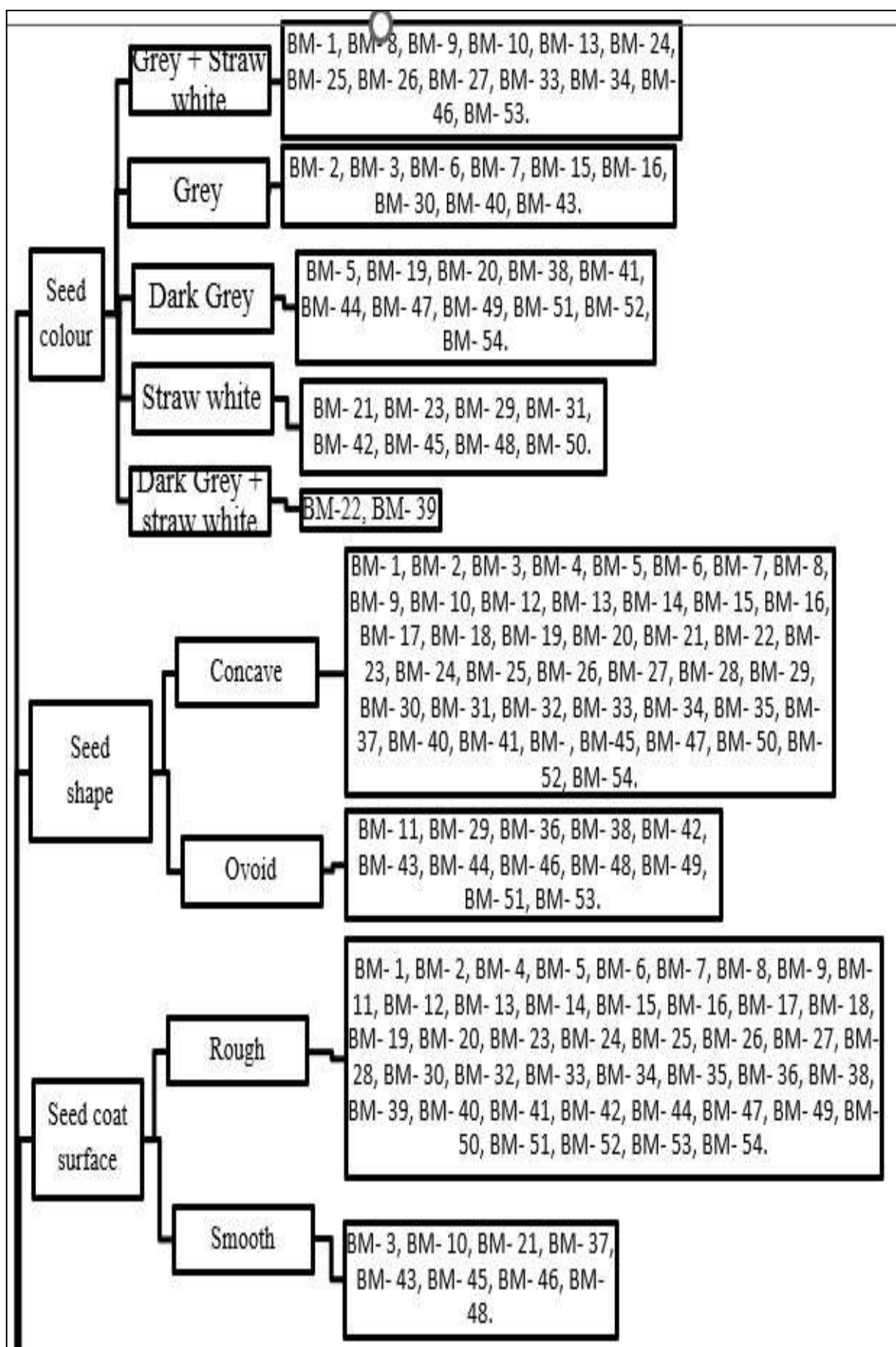
BM-32	0.00(HR)	18.41(MR)	6.00	0.00(HR)
BM-33	25.07(MR)	26.26(MR)	7.00	0.00(HR)
BM-34	0.00(HR)	11.30(MR)	4.00	0.00(HR)
BM-35	0.00(HR)	4.26(R)	4.00	0.00(HR)
BM-36	10.07(R)	18.12(MR)	6.00	0.00(HR)
BM-37	0.00(HR)	11.34(MR)	5.00	0.00(HR)
BM-38	0.00(HR)	23.40(MR)	7.00	0.00(HR)
BM-39	35.10(S)	27.22(MR)	4.00	0.00(HR)
BM-40	0.00(HR)	14.59(MR)	5.00	0.00(HR)
BM-41	0.00(HR)	18.51(MR)	6.00	0.00(HR)
BM-42	0.00(HR)	18.33(MR)	6.00	0.00(HR)
BM-43	0.00(HR)	11.44(MR)	5.00	0.00(HR)
BM-44	0.00(HR)	4.41(R)	3.00	0.00(HR)
BM-45	0.00(HR)	2.33(R)	4.00	0.00(HR)
BM-46	0.00(HR)	1.42(R)	3.00	0.00(HR)
BM-47	10.23(R)	2.35(R)	5.00	0.00(HR)
BM-48	25.01(MR)	23.35(MR)	7.00	0.00(HR)
BM-49	10.43(R)	16.33(MR)	6.00	0.00(HR)
BM-50	0.00(HR)	7.40(R)	5.00	0.00(HR)
BM-51	0.00(HR)	2.33(R)	3.00	0.00(HR)
BM-52	0.00(HR)	2.43(R)	5.00	0.00(HR)
BM-53	0.00(HR)	17.40(MR)	6.00	0.00(HR)
BM-54	0.00(HR)	18.44(MR)	6.00	0.00(HR)
CD at 5%	0.32	0.22	0.34	0.07
CV (%)	3.77	3.63	8.37	4.47
SEM	0.11	0.08	0.12	0.02
SE (d)	0.16	0.11	0.17	0.03
General Mean	7.93	15.25	5.42	0.16
Highest	50.10	28.50	8.00	5.55
Lowest	5.00	1.42	3.00	3.33

Table 4.4: Evaluation of barnyard millet germplasm for seed related parameters such as seed length and seed width

Entry No.	Seed dimensions	
	Seed length (mm)	Seed width (mm)
BM-1	3.20	2.44
BM-2	2.69	2.23
BM-3	2.79	2.03
BM-4	2.70	1.82
BM-5	2.62	1.99
BM-6	2.44	1.67
BM-7	2.77	1.87
BM-8	2.57	2.22
BM-9	2.73	2.19
BM-10	2.45	2.06
BM-11	2.40	1.82
BM-12	2.70	2.00
BM-13	2.80	1.94
BM-14	2.60	1.87
BM-15	2.74	1.98
BM-16	2.80	2.01
BM-17	2.92	1.85
BM-18	2.82	1.94
BM-19	2.62	1.75
BM-20	2.63	1.82
BM-21	2.91	1.92
BM-22	2.68	1.95
BM-23	2.79	1.93
BM-24	2.89	1.84
BM-25	2.62	2.01
BM-26	2.46	1.96
BM-27	2.75	2.08
BM-28	2.55	1.81
BM-29	2.87	2.03
BM-30	2.73	1.98
BM-31	2.67	1.46
BM-32	2.91	2.13
BM-33	2.65	1.86
BM-34	3.03	2.28
BM-35	2.86	2.11
BM-36	2.72	1.98
BM-37	2.73	2.44
BM-38	2.57	1.84

BM-39	2.75	2.02
BM-40	2.79	1.95
BM-41	2.63	1.65
BM-42	2.98	1.96
BM-43	2.50	1.82
BM-44	2.93	1.85
BM-45	2.95	1.72
BM-46	2.83	1.87
BM-47	2.27	1.70
BM-48	2.62	1.81
BM-49	2.51	1.74
BM-50	3.06	1.64
BM-51	2.17	1.59
BM-52	2.88	1.98
BM-53	2.82	2.06
BM-54	2.57	1.81
CD at 5%	0.02	0.03
CV (%)	0.76	1.30
SEM	0.009	0.013
SE (d)	0.012	0.018
General Mean	2.72	1.92
Highest	3.20	2.44
Lowest	2.17	1.46







Grain smut



Sheath blight



Leaf blight



Head smut

Plate-5 Important endemic diseases of barnyard millet under field conditions



Plate-6 Data recording for the seed attributing traits of harvested seeds of barnyard millet germplasm

4.4.4. Seed coat colour

The following seed coat colour were identified based on visual observation viz., grey + straw white, grey, dark grey, straw white, and dark grey + straw white (**Plate-7**). Among the 54 barnyard millet Germplasm, there were 13 genotypes with a grey + straw white seed coat colour, which accounts for 24.07 percent, 9 genotypes showed seeds with grey seed coat colour, which accounts for 16.67 percent, the dark grey seed coat colour was reported in 11 genotypes, which accounts for 20.37 percent, 8 genotypes had seeds with straw white seed coat colour, which accounts for 14.81 percent and only 2 genotype's seed showed dark grey + straw white colour, which accounts for 3.70 percent.

4.5. Analysis of variance for morphometric traits

The analysis of variance results for 54 different characters of barnyard millet germplasm were performed using a randomized complete block design, and the results are shown in **Appendix-II**. The mean squares due to genotypes were highly significant for all the studied variables. It shows that the examined germplasms were highly diverse.

4.6. Genetic components

Statistical calculations of genotypic, phenotypic and environmental variance, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and environmental coefficient of variation (ECV), heritability and genetic advance as percent of mean was performed to understand the nature of gene action and the variability expression of different characters prevailing in the population for selection as well as the breeding methods applied for their improvement. This facilitated the identification of desirable germplasm to be cultivated in the hills of Uttarakhand and used in the cross-breeding nursery to create new ideal varieties that would perform better in the changing environment. Various genetic component of genotypes are mentioned in **Table 4.5**

4.6.1 Genotypic and phenotypic variance

Higher genotypic variance was recorded for grain yield (32.53), fodder yield (24.14) and harvest index (7.12). Higher phenotypic variance was recorded for grain yield (32.54), fodder yield (24.15) and harvest index (7.12), while move towards the seed

attributing traits, lowest values of genotypic variance was recorded for basal tillers (0.01) and 1000 seed weight (0.01), productive tiller (0.02), days to maturity (0.03) and plant height (0.08). While lowest values of phenotypic variance were recorded for 1000 seed weight (0.01), basal tillers (0.02), productive tillers (0.03) and days to maturity (0.04).

4.6.2. Coefficient of variation (%)

Outcomes relating to genetic components, revealed that the high value reported for genotypic coefficient of variation was recorded for grain yield (35.56) and moderate value reported for genotypic coefficient of variation was recorded for fodder yield (11.79) seed length (10.40) and seed width (10.40), for phenotypic coefficient of variation the high value was recorded for grain yield (35.56) and moderate value was recorded for seed length (10.40) and the lowest genotypic coefficient of variation was recorded in biological yield (0.01) followed by days to maturity (0.13), and plant height (0.21), while lowest phenotypic coefficient of variation was recorded for biological yield (0.01), days to maturity (0.13) and plant height (0.23), for environment coefficient of variation was recorded low value for all the characteristics.

4.6.3. Heritability (h^2)

The analysis of the data revealed that the majority of characteristics were highly heritable except basal tiller (51.61%) which was categorized as moderate. Highest heritability was recorded for seed length (100.0%) and seed width (100.0%), harvest index (99.99%) and grain yield (99.98%).

4.6.4. Genetic advance (GA) & Genetic advance as percent of mean

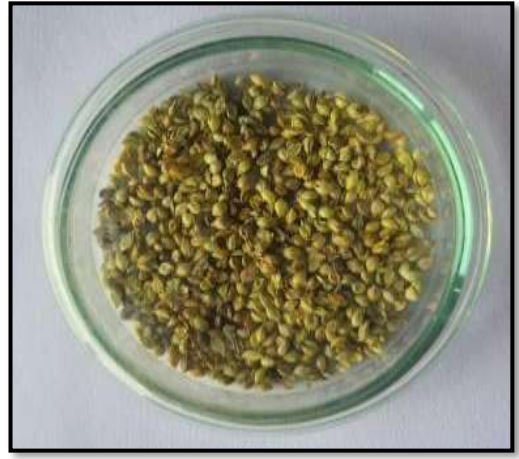
The genetic advance for grain yield (11.75), fodder yield (10.12) and harvest index (5.50) were high as compared to remaining parameters and the genetic advance as percent of mean for grain yield (73.25), biological yield (60.42), seed width (30.35), fodder yield (24.28) seed length (21.42) and harvest index (20.13) was high, moderate value for the genetic advance as percent of mean was not found and the low for the rest of the characters

Table 4.5: Detailed information of various genetic components of barnyard millet crop

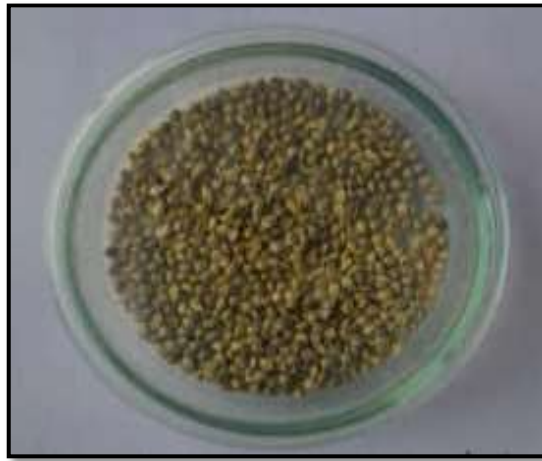
SI.No.	Character	General mean	Msg	Mse	Vg	Vp	Ve	GCV	PCV	ECV	h ²	GA	GA as % mean
1	Days to 50% flowering	76.11	0.34	0.004	0.11	0.12	0.004	0.44	0.45	0.08	96.56	0.68	0.89
2	Days to maturity	144.09	0.10	0.003	0.03	0.04	0.003	0.13	0.13	0.04	91.74	0.36	0.25
3	Plant height	139.14	0.26	0.02	0.08	0.10	0.02	0.21	0.23	0.09	83.73	0.54	0.39
4	Number of basal tillers	6.54	0.04	0.01	0.01	0.02	0.01	1.58	2.20	1.53	51.61	0.15	2.34
5	Number of productive tillers	2.33	0.07	0.02	0.02	0.03	0.01	5.49	6.96	4.29	62.03	0.21	8.90
6	Panicle length	15.90	0.76	0.01	0.25	0.26	0.01	3.15	3.19	0.53	97.28	1.02	6.40
7	Panicle weight	19.00	0.43	0.07	0.12	0.19	0.07	1.81	2.29	1.40	62.50	0.56	2.95
8	Grain yield	16.04	409.68	312.08	32.53	32.54	0.01	35.56	35.56	0.52	99.98	11.75	73.25
9	Fodder yield	41.68	73.68	1.25	24.14	24.15	0.01	11.79	11.79	0.01	99.97	10.12	24.28
10	1000 seed weight	3.12	0.04	0.001	0.01	0.01	0.001	3.46	3.60	1.01	92.11	0.21	6.84
11	Biological yield	0.51	0.08	0.01	0.02	0.02	0.001	0.01	0.01	0.01	95.89	0.31	60.42
12	Harvest index	27.31	26.11	4.74	7.12	7.12	0.001	9.77	9.77	0.12	99.99	5.50	20.13
13	Seed length	2.72	0.08	0.00	0.08	0.08	0.00	10.40	10.40	0.00	100.00	0.58	21.42
14	Seed width	1.92	0.08	0.00	0.08	0.08	0.00	10.40	14.73	0.00	100.00	0.58	30.35



Straw white



Grey



Dark grey

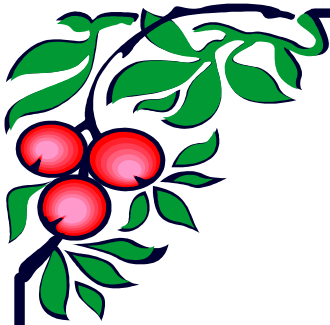


Grey + straw white

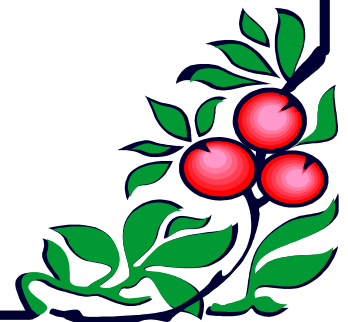


Dark grey + straw white

Plate-7 Variation in barnyard millet seed coat colour



DISCUSSION



The present investigation entitled “**Evaluation of barnyard millet germplasm for morphometric characterization and screening against important endemic diseases in mid-hills of Uttarakhand**” conducted during *Kharif*- 2022 at Plant Pathology Block, College of Forestry, Ranichauri have been discussed in this chapter along with possible reasons and available literature under the following headings:

5.1. Morphometric traits

5.2. Disease screening

5.3. Seeds attributing traits (harvested seeds)

5.4. Genetic components

5.1. Morphometric traits

Evaluation of 54 barnyard millet germplasm was done for both the qualitative and quantitative traits (field parameters). These findings can help us to identify the superior and better performing genotypes in terms of growth, yield and disease resistant lines. Apart from this, it could be helpful in regulating the seed quality, seed multiplication, seed production and seed certification process because of the variation in genetic makeup and the superior genotypes may be chosen to develop climate-resilient cultivar. Also, it is highly useful to set up distinctness, uniformity and stability of the cultivars. Qualitative characteristics such as, panicle compactness, inflorescence colour and shape or plant parts aid in the identification of material that is being segregated. A total of 3 qualitative, 12 quantitative traits, 4 seeds attributing traits (harvested seeds) and 4 endemic diseases were assessed for characterization of the barnyard accession. In present experiment, a total of 54 barnyard germplasm were visually observed and the appearance of genotypes was found unique.

The significant results were seen in the morphometric traits of barnyard millet such as for panicle compactness, genotypes were reported to be either compact or open, for inflorescence color, three different types of colors were observed such as green, dark purple and light purple and two different type of inflorescence shapes viz., cylindrical and globose/elliptical were reported. **Li et al. (2010)** reported that panicle compactness was an important factor and greatly influenced grain yield. **Upadhyaya et al. (2007)** observed that

inflorescence shape is an important parameter for characterization of germplasm. These variations could be due to genetic makeup of the genotypes or might be influenced by interaction of genetic and environmental factors combined. Similar variations were reported by **Kuraloviya *et al.* (2019)**, **Sood *et al.* (2015)** and **Ranjan *et al.* (2020)**.

During the investigation, significant variations were observed in growth and growth related traits of barnyard millet germplasm under open conditions. The parameters studied were days to 50% flowering, days to maturity, plant height (cm), number of basal tillers, number of productive tillers, panicle length (cm) and panicle weight (g). A significant variation in growth factors among different genotypes might possibly be due to their genetic structure along with the effect of edaphic and environmental factors or their combination. Days to 50% flowering and days to maturity was reported with a range of 63.67 to 88.00 days and 135.00 to 153.00 days respectively. Best genotype regarding days to 50% flowering, days to maturity was BM-20 with 63.67 days and 135.00 days, respectively. These findings are supported by various research workers such as **Rawat *et al.*, 2020** who reported significant variation in days to 50% flowering and days to maturity in barnyard millet while, days to maturity was recorded by **Nandini *et al.* (2020)** that varied from 114 to 75 days in barnyard millet.

Plant height varied significantly among different barnyard millet germplasm that ranged from 124.67 cm to 157.00 cm. It is an important plant growth character that significantly influences the overall yield of the crop. Variation in plant height might possibly be due to the crop's inherited genetic diversity. Other than that, soil and environmental conditions of the experimental site could also greatly influence the height of plants. **Joshi *et al.* (2013)** observed wide range of plant height between ranges of 182.13 cm to 65.06 cm in barnyard millet germplasm. Similar variations were also observed by **Rawat *et al.* (2020)** in barnyard millet who observed a plant height ranging between 123.67cm- 152.05 in barnyard millet.

Number of basal tillers and productive tillers play an important role in determining the growth type and influence the grain as well as fodder yield of barnyard millet. During the study, number of basal tillers and productive tillers ranged from 5.50 to 8.00 and 1.40 to 3.17 respectively. A wide variation for number of basal tillers that ranged from 5.25 to 2.52 was reported by **Geetanjali *et al.*, (2023)**. **Arunachalam and Vanniarajan (2012)** observed a broad variation for the number of productive tillers that varied from 3.50 to

1.30. Similar variation in number of productive tillers was observed by **Rawat *et al.* (2020)** and **Anuradha (2020)**.

Data regarding panicle length and panicle weight was recorded during the investigation and results revealed a wide variation among the genotypes. Values for panicle length ranged between 10.10 cm to 24.20 cm and that of panicle weight showed a range from 14.00 g to 26.67 g.

Significant variation in panicle length and weight was reported by **Koujalagi *et al.* (2018)** during a study in barnyard millet who reported similar results for panicle length ranging between 34.51 cm to 19.75 cm. **Sood *et al.* (2015)** also reported the variation in panicle weight ranging between 24.25 g to 4.20 g in barnyard millet.

Yield parameter:

A significant variation was also observed in yield and yield related parameters among the genotypes such as grain yield (kg/ha), fodder yield (kg/ha), 1000 seed weight (g), biological yield (kg/ ha) and harvest index (%). Yield of grain is an important factor while selecting a genotype for commercialization and successful adoption. During the investigation, variation in grain yield was observed that ranged from 1259.26 kg/ha to 1925.93 kg/ha. Data on fodder yield showed a range of 3444.44 kg/ ha to 5777.78 kg/ ha with genotype BM-1 having the highest values whereas, in case of 1000 seed weight, a range between 2.12 g to 3.85 g was reported. Biological yield represents a combined yield of grain and fodder which ranged from 4937.04 kg/ ha to 7029.63 kg/ ha with genotype BM-1 having the highest biological yield. Harvest index was worked out for the genotypes under study that shows the actual potential value of the crop and ranged from 19.38 % to 34.04 %. Various research workers reported the similar results and noted that these variations in yield related parameter could be due to number of factors either alone or in combination (**Kumar, 2013**). Genetic makeup or structure of plant plays a key role in influencing the yield, hence, was proved to be an imported factor in determining the yield and yield related parameters in different genotypes of barnyard millet (**Geetanjali *et al.*, 2023**). Apart from genetic makeup of plant, combined effect of environmental and edaphic factor proved to be crucial in influencing the yield related traits in barnyard millet. (**Yadav and Yadav, 2013**) reported significant variation in fodder yield ranging between 6547

kg/ha to 5180 kg/ha in barnyard millet. (**Samantha et al., 2022**) and **Vimalan et al., 2019**) also reported variation in fodder yield and harvest index in barnyard millet in a separate study respectively. Variation in 1000-seed weight that ranged from 1.99g to 3.31g was recorded by **Karad et al. (2013)**. Similar findings for grain yield have also been reported by **Ganapathy et al. (2011)**, **Bisht et al. (2015)**, **Rawat et al. (2020)**.

5.2. Disease screening

Barnyard millet is known to be affected by several diseases (**Pall et al., 1980**). Grain smut, leaf blight, sheath blight and head smut are a major production constraint causing heavy yield loss in hilly regions of Uttarakhand. In present experiment, fifty-four barnyard millet germplasm were screened for grain smut, leaf blight, sheath blight and head smut of which only two barnyard millet germplasm lines were found immune against all the studied endemic barnyard millet diseases.

During the screening of barnyard millet germplasm against grain smut disease it was reported that eleven germplasm lines were found resistant, four were found moderately resistant, four lines showed susceptibility and the remaining germplasm lines were found highly resistant. The present results are in agreement with the previous study made by **Rawat et al. (2020)** who reported screened seven advance breeding lines and three check varieties for grain smut and two lines were identified as high yielding, early maturing as well as grain smut resistant lines. Similar findings were observed by **Nagaraja and Jayarame (2010)** and **Kumar (2016)** in barnyard millet

Fifty-four barnyard millet germplasm were screened for sheath blight disease and results revealed a significant variation among the genotypes and disease was reported in each of the tested Germplasm ranging from highly susceptible to highly resistant. **Kumar and Dinesh (2009)** stated that severity of disease is highly influenced by high R.H (~70%) and temperatures that are known to favour sheath blight disease incidence. **Patro et al., 2019** in an experiment on barnyard millet screening for sheath blight disease revealed that none of the test lines was immune due to difference in climatic conditions of that area, which made the genotypes susceptible to disease. The present study results are also in close agreement with the findings of **Jain and Tiwari (2013)** in proso millet.

Leaf blight is one of the vital foliar diseases in barnyard millet. It is a polycyclic disease dependent on relative humidity greater than 90 per cent and temperature above 15.5°C for disease progression. During the study it was noted that all the germplasm were

found resistant to leaf blight. **Ramesh *et al.* (2021)** stated that resistant trait for leaf blight was governed by polygenic genes and was quantitative in nature while unfavourable weather conditions viz., rainfall, soil moisture, humidity and temperature also favoured the disease development. Thirty-two cultivars were screened against leaf blight by **Jain (2021)** in finger millet and the results revealed that twenty two cultivars were found susceptible and nine cultivars were highly susceptible and one was reported resistant to leaf blight. Possible reason for this might be due to the genetic makeup of crop that might be responsible for it being either susceptible or resistant to diseases. Higher humidity and temperature might have favoured the development of the disease up to a certain extent. Similar results were reported by **Kumar *et al.* (2016)**.

5.3. Seed attributing traits (harvested seeds)

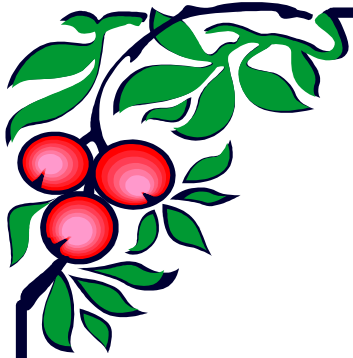
Seed coat surface, seed coat color, seed shape, seed length and width were studied during the present investigation. Seed related characters are important traits in developing consumer preference and also important for selection process of a genotype. Seed related traits could be used as a genetic marker in identifying a genotype with desired traits. Variation in seed attributing traits was observed. Seed coat surface was noted as rough or smooth. Two types of seed shape was observed during the study i.e. ovoid and concave. The seed coat colour were identified based on visual observation i.e., grey + straw white, grey, dark grey, straw white, and dark grey + straw white. It was observed that 85.18 percent of seeds had rough seed coat surface whereas 14.81 percent had smooth surface. In case of seed shape 77.78 percent were found to have concave shape and the remaining 22.22 had ovoid seeds. Significant variation in seed coat colour was also recorded among the studied germplasm. Variations in seed related traits could possibly be due to combined effect of genetic structure of genotypes along with the environmental and soil conditions of the growing site as reported by **Kumar *et al.*, 2019** in finger millet for seed coat surface. These results are also in close agreement with the findings of **Mishra *et al.*, 2022** and **Nilavarasi *et al.*, 2020** who reported variation in seed coat colour and seed shape respectively. Seed dimensions play important role in determining functional trait in the germination and seedling establishment process (**Khurana and Singh, 2000**). Variation in seed dimension (length and breadth) might possibly be due to availability of moisture content in soil as well in air, required mineral content in soil etc. **Kumar *et al.* (2016)** also reported variation in seed dimensions (length and breadth) that varied from 2.74 mm to

2.61 mm and 2.23 mm to 1.96 mm respectively.

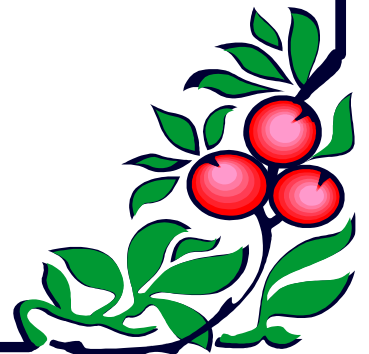
5.4. Genetic components

Computation of genetic components plays an important role in crop improvement programme because greater genetic variability ensures better chances of producing desired genotypes. The estimates of phenotypic and genotypic coefficient of variation indicated that the values of phenotypic coefficient of variation are higher than of GCV. But the differences were closer between these two estimates for all the characters that indicating the genetic expression of characters under study was less influenced by the environment. Higher genotypic coefficient of variation for grain yield and fodder yield was reported by **Reddy *et al.*, 2013** in finger millet. Higher phenotypic coefficient of variation for grain yield and fodder yield was reported by **Anuradha *et al.*, 2017** in little millet. Higher phenotypic coefficient of variation than genotypic coefficient of variation for grain yield and fodder yield reported by **Chavan *et al.*, 2019** in finger millet. However, for majority of the traits the environmental coefficients of variation (ECV) estimates were lower than both genotypic and phenotypic coefficients of variations. This implied that the environmental role was less for the expression of such characters (**Singh and Narayana, 1993**).

It was observed that all the characters showed higher heritability except basal tillers which proves the clues that direct selection for particular traits because these traits indicate the possibility of additive gene action and will go for selection direct. High heritability for yield and its contributing traits was reported by **Guleria *et al.* (2019)** in soyabean and **Kumar *et al.* (2014)** in wheat. High heritability coupled with high genetic advance as percent of mean indicating that these characters were under the influence of additive gene action and selection. Breeding for these characters in barnyard millet would be fruitful. Similar result was observed by **Koujalagi *et al.*, 2018** for yield and contributing traits in barnyard millet. However, higher genetic advance was recorded for all the traits except basal tiller which was recognised as moderate in the present experiment. Traits have higher heritability along with higher genetic advance can be select directly for further breeding programme, because these traits governed by additive gene action. These results are in close agreement with the findings of **Ganapathy *et al.* (2011)** and **Singamsetti *et al.* (2018)** in finger millet.



*SUMMARY
AND
CONCLUSION*



The present investigation entitled “**Evaluation of barnyard millet germplasm for morphometric characterization and screening against important endemic diseases in mid-hills of Uttarakhand**” was undertaken to know the morphometric variation for different qualitative and quantitative traits, genetic diversity and screening for endemic disease of barnyard millet germplasm.

The experimental material comprised of fifty-four barnyard millet germplasm including two check varieties. The experiment was conducted in Randomized Block Design during *Kharif*-2022 at Plant Pathology Block, College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand. The observations were recorded for morphometric traits, disease severity and seed attributing traits. Field parameters studied during the crop growth period were days to 50 percent flowering, days to maturity, number of basal tillers, number of productive tillers, panicle length, panicle weight, plant height, grain yield, fodder yield, 1000 seed weight, biological yield and harvest index. Data was statistically examined to determine the phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic advance as percent of mean. The key finding of the study and conclusions made out of it is outlined below:

6.1. Assessment of morphometric traits

- Significant variability was recorded among the studied genotypes for three qualitative traits viz., inflorescence colour, inflorescence shape and panicle compactness.
- Considerable variation was recorded for days to 50 % flowering that ranged from 63.67 to 88.00 days. The early flowering germplasms were BM-20, BM-1, BM-2, BM-48 and BM-41 that took less than 68 days to 50 percent flowering.
- Out of the fifty-four barnyard millet germplasm studied, days to maturity ranged between 135 to 153 days. Some of the early maturing genotypes were BM-20, BM-1, BM-18, BM-24 and BM-19 while some the late maturing genotypes were BM-27, BM-33, BM-32 and BM-52.

- Genotype BM-1 followed by BM-34, BM-11, BM-16 and BM-14 were identified as higher grain yield. These five entries also showed high mean performance for grain yield. Out of the fifty-four entries, two entries i.e., BM-1 and BM-34 shown high mean performance for grain yield and some of the yield components. The genotypes mentioned above and some other lines having high mean performance for characters other than grain yield may be used as donor parents in hybridization programme for improving the characters.
- The maximum 1000 seed weight was recorded in BM-1 followed by BM-34, BM-22, BM-20 and BM-18.
- A considerable variation was observed for character such as plant height among the studied genotypes that ranged from 124.67 cm to 157.00 cm. The highest plant height was achieved in BM-36 (157.00 cm) followed by BM-21 and BM-31 with 148.00 cm each while, the lowest plant height was achieved in BAR BM-44 (124.67 cm).
- Panicle length and panicle weight showed considerable variability among the studied genotypes. Panicle length reported a range of 10.10 cm to 24.20 cm with an overall mean value of 15.9 cm whereas, panicle weight showed a range from 14.00 g to 26.67 g with the general mean of 19.00.
- A considerable variation was observed for yield and yield related traits such as grain yield, fodder yield, 1000 seed weight and biological yield but two germplasm lines viz., BM-1 and BM-34 were as identified superior for all yield contributing traits. Highest grain yield was recorded in genotype BM-1 (1925.93 Kg/ha) followed by BM-34 (1901.23 Kg/ha). Fodder yield ranged between 3444.44 kg/ha to 5777.78 kg/ha with genotype BM-1 showing the highest yield of 5777.78 Kg/ha. The highest 1000 grain weight was recorded in genotype BM-1 (3.85 g) followed by BM-34 (3.80 g).
- Biological yield showed a range from 4907.41 kg/ha to 7029.63 kg/ha with highest biological yield in genotype BM-1 (7029.63 Kg/ha) followed by BM-34 (6970.37 Kg/ha) and BM-46 (6888.89 Kg/ha).

6.2. Disease screening

- Out of fifty-four barnyard millet germplasm lines, two germplasm lines viz., BM-1 and BM-34 are found immune for all the endemic diseases of barnyard millet.
- In case of screening against grain smut disease, thirty-four germplasm lines were found highly resistant, six germplasm lines were found moderate resistant and four germplasm lines were found to be susceptible for grain smut disease.
- Sheath blight disease was reported in all the studied genotype ranging from moderate to highly resistant. No germplasm line was found susceptible to sheath blight disease.
- For leaf blight, all the germplasm lines were recorded resistant. Mean value of percent disease incidence for leaf blight ranged in between 3.00 % to 8.00% with a general mean of 5.42%.
- Out of the total examined genotypes, only two genotypes i.e. BM-18 and BM-24 with 3.33% and 5.55% disease incidence respectively, were found resistant and the remaining genotypes were reported to be highly immune to head smut disease.

6.3. Seed attributing traits (harvested seeds)

- Significant variation was recorded in seed attributing traits viz., seed coat surface, seed coat colour, seed shape and seed dimensions.
- A slight variation was recorded for seed dimensions viz., seed length and seed width. Seed length and width showed a range between 2.17 mm to 3.20 mm and 1.46 mm to 2.44 mm respectively with BM-1 and BM-34 showing the highest values.

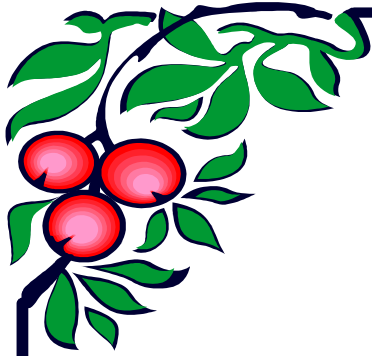
6.4. Genetic components

- Highest phenotypic and genotypic coefficient of variation was observed for grain yield, fodder yield, seed width and seed length whereas, lowest values for genotypic and phenotypic values were reported in number of basal tillers and 1000 seed weight respectively.
- For genotypic and phenotypic coefficient of variation highest values were reported for grain yield whereas, lowest was reported for biological yield.
- All the traits had higher heritability along with moderate to high genetic advance except basal tillers indicating that selection for these traits would be effective due to additive gene action.

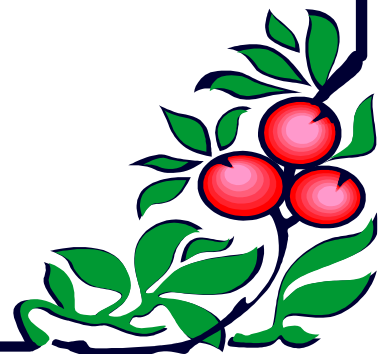
- Genetic advance was recorded highest for grain yield, fodder yield and harvest index. Highest genetic advance as percent of mean was observed in grain yield followed by biological yield and seed width. Days to maturity had lowest value to genetic advance as percent of mean.
- Phenotypic coefficient of variation was recorded highest for seed width whereas; there was no significant change in genotypic coefficient of variation and genetic advance.
- Genetic advance as percent of mean was recorded highest for seed width as compared to seed length.

Conclusion

Based on the findings of present investigation, it may be concluded that the information generated on morphometric traits, disease screening and seed attributing traits can be used as base for the selection of desirable genotypes with specific traits for utilization in crop improvement programme. On the basis of genetic values for morphometric traits and seed attributing traits, the germplasm showed high to moderate heritability accompanied with high genetic advance that could be utilized in the barnyard millet crossing programme for developing high yielding resistant varieties. Considerable variation was noted for parameters under observation among all the studied germplasm, however, two germplasm i.e., BM-1 and BM-34 were identified as high yielding as well as resistant to all endemic diseases. Hence, it is concluded that these two germplasm lines (BM-1 and BM-34) are of remarkable value and may be further used in the breeding programme to develop high yielding improved varieties with resistance to diseases.



*LITERATURE
CITED*



LITERATURE CITED

- Adugna W. 2002.** Genetic diversity analysis of linseed *Linum usitatissimum* (L.) in different environments. Thesis, Ph.D. University of the Free State, Bloemfontein, South Africa. 1-234pp.
- Allard, R.W. 1960.** Principles of plant breeding. New York, John Wiley and Sons. 1-485.
- Amgai, R.B., Chhetri, T.B., Budhathoki, S.K., Upadhyaya, M.P., Khatiwada, S.P. and Mudwari, A. 2013.** Variation on agro-morphological characteristics among Nepalese finger millet germplasm. In: *Proceedings of the 27th National Summer Crops Workshop*. April (Vol: 2) (Vol. 18, p. 20th).
- Anonymous. 2021.** Small millet statistical production data of 2020-21. <https://www.indiastat.com/table/small-millet/selected-state-wise-area-production-productivity-s/1409333> accessed on 5-12-2022.
- Anonymous. 2022.** Knowledge paper on millets the future super food for India. [Report Millets 2022 \(Print Version\) \(1\).pdf](#) accessed on 5-12-2022.
- Anuradha, N., Patro, T.S.S.K., Divya, M., Rani, Y.S. and Triveni, U. 2017.** Genetic variability, heritability and correlation of quantitative traits in little millet genotypes. *J. pharmacogn. phytochem.* **6**(6): 489-492.
- Arunachalam, P. and Vanniarajan, C. 2012.** Genetic parameters and quantitative traits association in barnyard millet (*Echinochloa frumentacea*). *Plant Arch.* **12**(2): 691-694.
- Arunachalam, P., Vanniarajan, C. and Nirmalakumari, A. 2012.** Consistency of barnyard millet (*Echinochloa frumentacea*) genotypes for plant height, duration and grain yield over Environments. *Madras Agric. J.* **99**(1-3): 11-13.
- Arya, R., Bhatt, A., Kumar, V. and Singh, D.P. 2017.** Correlation analysis of some growth, yield and quality parameters of barnyard millet (*Echinochloa frumentacea* (Roxb.) Link) Germplasm. *J. pharmacogn. phytochem.* **6**(5): 1426-1429.

- Baryeh, E.A. 2002.** Physical properties of millet. *Journal of Food Engineering*. **51**(1): 39-46.
- Bendale, V.W., S.G. and Pethe, U.B. 2002.** Genetic variability, correlation and path analysis in finger millet (*Eleusine coracana* Gaertn.). *J. Soils Crops*. **12**: 187- 191.
- Bhat, B.V., Arunachalam, A., Kumar, D., Tonapi, V.A. and Mohapatra, T. 2019.** Millets in the Indian Himalaya. New Delhi, Indian Council of Agricultural Research. 1- 84p.
- Bisht. A, Jeena, A.S. Singh, N. K. and Singh, S. P. 2015.** Morphological characterization and genetic analysis of finger millet [*Eleusine coracana* (L.) Gaertn]. *Front. In. Crop. Imp. J*, **3**(1):9-14.
- Bunkar, D.S., Goyal, S.K., Meena, K.K. and Kamalvanshi, V. 2021.** Nutritional, functional role of kodo millet and its processing: a review. *Int. J. curr. microbiol. appl. sci.* **10**(01): 1972-1985.
- Burton, G.W. and Devane, E.W. 1953.** Estimating heritability in all tall fescus (*Festuca arundinaceae*) from replicated clonal material. *Agric. J.* **45**(10): 478-481.
- Chauhan, B. and Johnson, D.E. 2011.** Ecological studies on *Echinochloa crusgalli* and the implications for weed management in direct-seeded rice. *Crop Prot.* **30**(11): 1385-1391.
- Clayton, W.D. and Renvoize, S.A. 2006.** Genera Graminum: Grasses of the world. London, Royal Botanical Gardens. **13**: 1-389.
- Cochran, W. G. and Cox, M. G. 1992.** Experimental design. New York, USA; John Wiley's sons Inc. 106-117.
- Das, I. K., Nagaraja, A. and Tonapi, V. A. 2016.** Diseases of millets-a ready reckoner. *Krishi Publication and Data Inventory Repository*. 34p.
- Dhanalakshmi, R., Subramanian, A., Thirumurugan, T., Elangovan, M. and Kalaimagal,**

- T. 2019.** Genetic variability and association studies in barnyard millet (*Echinochloa frumentacea* (Roxb.) Link) germplasm under sodic soil condition. *Electron. J. Plant Breed.* **10**(2): 430-439.
- Dikshit, N. and Nizar, M.A. 2013.** Assessment of diversity and agro-morphological characteristics of some landraces of little millet germplasm from india. *J. Agric. Sci. Technol.* **38**(1): 46-50.
- Divya, M., Patro, T.S.S.K., Rani, Y.S., Triveni, U. and Anuradha, N. 2017.** Detection of resistant entries of little millet against banded blight disease in cited by *Rhizoctonia Solani* Kuhn. *J. Crop. Improv.* **5**(1): 74-75.
- Gajalakshmi, R. and Chitdeshwari, T. and Maragatham, S. and Ravikesavan, R. 2022.** Zinc nutrition for improving the growth and yield of barnyard millet (*Echinochloa frumantacea* L.). *Int. J. plant soil sci.* **34**(21): 657-664.
- Ganapathy, S., Nirmalakumari, A. and Muthiah, A.R. 2011.** Genetic variability and interrelationship analyses for economic traits in finger millet germplasm. *World J. Agric. Sci.* **7**(2): 185-188.
- Geethanjali, S., Dhandapani, M. and Sivakumar, V. 2023.** Genetic diversity and variability in barnyard millet [*Echinochloa frumentaceae* (L.)] germplasm based on morphological traits. *Madras Agric. J.* **110**(1): 1-3.
- Guleria, H., Kumar, P., Jyoti, B., Kumar, A., Paliwal, A. and Paliwal, A. 2019.** Genetic variability and correlation analysis in soybean (*Glycine max* (L.) Merrill) genotypes. *Int. J. Chem. Stud.* **7**(1): 1928-1932.
- Gupta, A., Joshi, D., Mahajan, V. and Gupta, H. S. 2010.** Screening barnyard millet germplasm against grain smut (*Ustilago panici-frumentacei* Brefeld). *Plant Genet. Resour.* **8**(1): 52-54.

- Gupta, A., Mahajan, V., Kumar, M. and Gupta, H.S. 2009.** Biodiversity in the barnyard millet (*Echinochloa frumentacea* Link, Poaceae) germplasm in India. *Genet. Resour. Crop Evol.* **56**(6): 883-889.
- Haradari, C., Ugalat, J. and Nagabhushan. 2012.** A study on character association genetic variability and yield component of finger millet (*Eleusine coracana* (L.) Gaertn). *J. of Crop and Weed.* **8**(2): 32-35.
- Jain, A. and Tripathi, S. 2007.** Management of grain smut (*Macaipinomyces sharmae*) in little millet. *Indian Phytopath.* **60**(4): 467-471.
- Jain, A.K. 1995.** Management of head smut in kodo-millet (*Paspalum scrobiculatum* L.). *Ann. Agric. Sci.* **16**(2): 172-178.
- Jain, A.K. 2021.** Resistance in finger millet (*Eleusine coracana* L. Gaertn.) cultivars against major diseases. *J. plant pathol. Microbiol.* **1**(1): 07-11.
- Jain, A.K. and Gupta, A.K. 2010.** Occurrence of banded leaf and sheath blight on foxtail and barnyard millets in Madhya Pradesh. *Ann. Plant Prot. Sci.* **18**(1): 268-270.
- Jain, A.K. and Joshi, R.P. 2020.** Efficacy of fungicides for management of banded leaf and sheath blight of kodo millet caused by *Rhizoctonia solani* Kuhn. *Ann. Plant Prot. Sci.* **28**(1): 60-62.
- Jain, A.K. and Tiwari, A. 2013.** Evaluation of promising genotypes of proso millet against banded leaf and sheath blight disease caused by *Rhizoctonia solani* Kuhn. *Mysore. J. Agric. Sci.*, **47**(3): 648-650.
- Jain, A.K., 1999.** Evaluation of fungicides for the control of head smut in kodo millet. *Indian Phytopathol.* **52**(4): 423-424.

- Jain, A.K., Amrita, T. and Dhingra, M.R. 2013.** Resistance against head smut in kodo millet (*Paspalum scrobiculatum* L.). *Mysore J. Agric. Sci.* **47**(3): 645-647.
- Jain, A.K., Joshi, R.P. and Singh, G. 2014.** Identification of host resistance against banded leaf and sheath blight of foxtail millet. *JNKVV Res. J.* **48**: 171-175.
- Jain, A.K., Kumar, A., Chouhan, S.S. and Joshi, R.P. 2018.** Status and management of banded leaf and sheath blight of little millet caused by *Rhizoctonia solani* Kuhn with chemicals. *Ann. Plant Prot. Sci.* **26**(1): 122-126.
- Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955.** Estimation of genetic and environmental viability in soyabean. *Agron. J.* **47**(7): 314-318.
- Joshi, P.K. and Agnihotri, A.K. 1984.** Millet production in India: Problems and prospects. *Agril. situation in India.* **39**: 329-333.
- Joshi, R.P., Jain, A.K. and Chauhan, S.S. 2014.** Collection and evaluation of kodo millet land races for agro-morphological traits and biotic stresses in Madhya Pradesh. *JNKVV Res. J.* **48**(2): 162-169.
- Joshi, R.P., Jain, A.K., Chauhan, S.S. and Singh, G. 2015.** Characterization of barnyard millet (*Echinochloa frumentacea* (Roxb.) Link.) landraces for agro-morphological traits and disease resistance. *Electron. J. Plant Breed.* **6**(4): 888-898.
- Joshi, V. 2013.** Assessment of genetic variability and identification of genotypes for different traits in Barnyard millet (*Echinochloa* spp). *Int. J. agric. environ. food sci.* **4**: 65-67.
- Kadam, P.R. and Sharma, K.K. 2018.** Identification and severity of Important Diseases of Foxtail Millet [*Setaria italica* (L.) Beauv.]. *Contemp. res. India.* **2**: 179-183.
- Karad, S. R. and Patil, J. V. 2013.** Assessment of genetic diversity among finger millet

[*Eleusine coracana* (L.) Gaertn] genotypes. *Int. J. of. Int. Sci. Inn. Techo.*, 2(4): 37-43.

Khurana, E. and Singh, J. S. 2000. Ecology of seed and seedling growth for conservation and restoration of tropical dry forest: A review. *Environ. Conserv*: **28**(1) 39–52.

Koujalagi, D., Negi, A.S., Jeena, A.S. and Singh, S.P. 2018. Genetic variability studies in barnyard millet (*Echinochloa frumentaceae*) collection. *Progressive Res. Int. J.* **13** (3): 187-19.

Kumar, A., Chawla, H.S., Jeena, A.S. and Rohit. 2019. Morphological Characterization of Finger Millet Germplasm Collected from Uttarakhand Hills for Qualitative Traits. *Int. J. Curr. Microbiol. App. Sci.* **8**(9): 2105-2109.

Kumar, A., Jain, A.K., Singh, P. and Lal, N. 2017. Screening of little millet germplasm against grain smut caused by *Macalpinomyces sharmae*. *Int. J. Curr. Microbiol. App. Sci.* **6**(4): 2187-2196.

Kumar, A., Tripathi, M.K., Joshi, D. and Kumar, V. 2021. Millets and Millet Technology. Singapore, *Springer*. 1- 438p.

Kumar, B. 2011. First record of smut disease of foxtail millet caused by *Ustilago crameri* Korn. *J. mycol. plant pathol.* **41**(3): 459.

Kumar, B. 2012. Management of important diseases of barnyard millet (*Echinochloa frumentacea*) in mid-western Himalayas. *Indian. Phytopathol.* **65**(3): 300.

Kumar, B. 2013. Management of grain smut disease of barnyard millet (*Echinochloa frumentacea*). *Indian Phytopathol.* **66**(4): 403-405.

Kumar, B. 2016. Status of small millets diseases in Uttarakhand. *Int. J. Plant Prot.* **9**(1): 256-

263.

- Kumar, B. and Dinesh, P. 2009.** First record of banded sheath blight disease of barnyard millet caused by *Rhizoctonia solani*. *J. Mycol. Plant Pathol.* **39**(2): 352-354.
- Kumar, B. and Srivastava, J.N. 2020.** Barnyard Millet/Japanese Millet or Sawan (*Echinochloa frumentacea* L.) Diseases and Their Management Strategies. In Diseases of Field Crops: Diagnosis and Management. India, Apple Academic Press. 95-204p.
- Kumar, B., Kumar, J. and Srinivas, P. 2008.** A first record of head smut in barnyard millet from mid hills of Uttarakhand. *J Mycol. Plant Pathol.* **38**(1): 142-143.
- Kumar, B., Kumar, M. and Rai, R.S. 2002.** Genetic variability in ragi (*Eleusine coracana* (L.) Gaertn). *J. of appl. Biology.* **12**(12): 4-6.
- Kumar, Bijender. 2013.** Management of grain smut disease of barnyard millet (*Echinochloa frumentacea*). *Indian Phytopathol.* **66**(4): 403-405.
- Kumar, D., Patel, S., Naik, R.K. and Mishra, N.K. 2016.** Study on physical properties of indira kodo-I (*Paspalum scrobiculatum* L.) millet. *Int. J. Eng. Rses. Technol.* **5**(1): 39-45.
- Kumar, N., Markar, S. and Kumar, V. 2014.** Studies on heritability and genetic advance estimates in timely sown bread wheat (*Triticum aestivum* L.). *Biosci. Discovery.* **5**(1): 64-69.
- Kuraloviya, M., Vanniarajan, C., Vetriventhan, M., Babu, C., Kanchana, S. and Sudhagar, R. 2019.** Qualitative characterization and clustering of early-maturing barnyard millet (*Echinochloa* spp.) germplasm. *Electron. J. Plant Breed.* **10**(2): 535-541.
- Li, F., Liu, W., Tang, J., Chen, J., Tong, H., Hu, B., Li, C., Fang, J., Chen, M., Chu, C. 2010.** Rice Dense and Erect Panicle 2 is essential for determining panicle outgrowth and elongation. *Cell Res.* **20**(7): 838–849.

- Lilian, J., Paul, K., Daniel, O., Mgonja, M., Bernard, T., Nicholas, L. and Henry, O. 2016.** Yield losses and path coefficient analysis of head smut disease (*Tolyposporium penicillariae*) in pearl millet genotypes. *Am. J. Exp. Agric.* **13**(3): 1-10.
- Maitra, S. 2020.** Potential horizon of brown-top millet cultivation in drylands: A review. *Crop Res.* **55**(1 & 2): 57-63.
- Manimekalai, M., Dhasarathan, M., Karthikeyan, A., Murukarthick, J., Renganathan, V.G., Thangaraj, K., Vellaikumar, S., Vanniarajan, C. and Senthil, N. 2018.** Genetic diversity in the barnyard millet (*Echinochola frumentacea*) germplasms revealed by morphological traits and simple sequence repeat markers. *Curr. Plant Biol.* **14**: 71-78.
- Mishra, N., Tiwari, S., Sapre, S., Nema, S., Sahu, V.K., Tantwai, K. and Tiwari, P.N. 2022.** Qualitative characterization and categorization of barnyard millet (*Echinochloa* spp.) accession, collected from different regions of India. *Bio. For. Int. J.* **14**(3): 928-932.
- Mitich, L. W. 1990.** Intriguing world of weeds. Barnyard grass. *Weed Tech.* **4**(4): 918-920.
- Nagaraja, A. and Jayarame, G. 2010.** Screening barnyard millet accessions for reaction to grain smut. *Env. Ecol.*, **28**(1B): 718-721.
- Nagaraja, A. and Reddy, B.A. 2010.** Banded blight-a new record on finger millet in Karnataka. *J. Mycopathol. Res.* **48**(1): 169-170.
- Nagaraja, A., Kumar, J., Jain, A.K., Narasimhudu, Y., Raghuchander, T., Kumar, B. and Gowda, B.H. 2007.** Compendium of small millets diseases. Published by *Project coordinator, All India Coordinator Small Millets Improvement Project.* 1-75.
- Nagaraja, T.E., Nandini, C., Bhat, S., Palanna, K.B., Ganiger, P.C., Sukanya, T.S., Saritha, H.S., Parveen, S.G. and Vinutha, D.N. 2022.** GPUF 3: A new high yielding

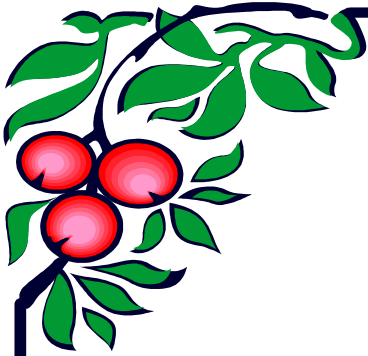
- foxtail millet variety (*Sateria italica*). *Electron. J. Plant Breed.* **13**(3): 810-819.
- Nandini, C., Bhat, S., Saritha, H.S., Pandey, C.D., Sushil Pandey, P., Bai, L. and Gowda, J. 2020.** Characterization of barnyard millet (*Echinochloa frumentaceae* (Roxb.) Link) germplasm for quantitative traits to enhance its utilization. *Electron. J. Plant Breed.* **11**(04): 1066-1072.
- Napper, D.M. 1965.** Grasses of Tanganyika with keys for identification. *Bull. Min. Agric. For. Wildlife.* **18**: 146-148.
- Nilavarasi, R., Sujatha, K., Geetha, R. and Vanniarajan, C. 2020.** Morphological characterization and evaluation of barnyard millet varieties, cultivars and mutants for varietal identification. *J. Pharmacogn. Phytochem.* **9**(1): 1600-1604.
- Nilavarasi, R., Sujatha, K., Geetha, R. and Vanniarajan, C. 2020.** Varietal characterization and categorization of barnyard millet (*Echinochloa frumentaceae* L.) varieties, cultivars and mutants for varietal identification. *Electron. J. Plant Breed.* **11**(02): 487-493.
- Nirmalakumari, A., Salini, K. and Veerabadrhan, P. 2010.** Morphological characterization and evaluation of little millet (*Panicum sumatrense* Roth. ex. Roem. and Schultz.) germplasm. *Electron. J. Plant Breed.* **1**(2): 148-155.
- Nirubana, V., Ganesamurthy, K., Ravikesavan, R. and Chitdeshwari, T. 2017.** Genetic variability studies for yield and yield components in kodo millet (*Paspalum scrobiculatum* L.). *Electron. J. Plant Breed.* **8**(2): 704-707.
- Pall, B.S., Jain, A.C. and Singh, S.P. 1980.** Diseases of lesser millets. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jawalpur (Madhya Pradesh), India, 55-57.
- Patel, S.N., Patil, H.E., Modi, H.M. and Singh, T.J. 2018.** Genetic variability study in little millet (*Panicum miliare* L.) genotypes in relation to yield and quality traits. *Int. J. Curr. Microbiol. App. Sci.* **7**(6): 2712-2725.
- Patil, H.E., Patel, J.V., Vavdiya, P.A., Naghera, Y.V. and Intwala, C.G. 2016.** A High Yielding Little Millet Variety GNV-3 for Cultivation in Gujarat. *J. Trop. Agric.* **34**(6): 1403-1406.
- Patil, S., Kauthale, V., Aagale, S., Pawar, M. and Nalawade, A. 2019.** Evaluation of finger millet [*Eleusine coracana* (L.) Gaertn.] accessions using agro-morphological characters. *Indian J. Agric. Res.* **53**(5): 624-627.

- Patnaik, V.K., Mahto, J.L. and Haider, Z.A. 2004.** Heritability studied in Finger millet (*Eleusine coracana* (L.) Gaertn) genotypes. *J. Soils and crops*. **16**(1): 127-129.
- Patro, T.S.S.K., Divya, M., Rani, Y.S., Triveni, U. and Anuradha, N. 2017.** Evaluation Of Proso Millet (*Panicum Miliaceum* L.) Genotypes Against Emerging Malady of Sheath Blight Caused By *Rhizoctonia Solani*, Kuhn Un Der In Vivo. *Progressive res. Int. J.* **12**: 103-104.
- Patro, T.S.S.K., Georgia, K.E., Kumar, S.R., Anuradha, N., Rani, Y.S., Triveni, U. and Jogarao, P. 2020.** Screening for identification of resistant sources of proso millet varieties against *Rhizoctonia solani* Kuhn. Inciting banded blight (BB) disease. *J. pharmacogn. phytochem.* **9**(5): 1273-1274.
- Patro, T.S.S.K., Meena, A., Divya, M. and Anuradha, N. 2018.** Eco-friendly management of incitant *Rhizoctonia solani*, the causing sheath blight in Kodo millet. *J. pharmacogn. phytochem.* **7**(4): 3168-3171.
- Patro, T.S.S.K., Meena, A., Divya, M. and Anuradha, N. 2018.** Evaluation of Kodo millet varieties resistant sources against banded blight (BB) disease incited by *Rhizoctonia solani* Kuhn *J. pharmacogn. phytochem.* **7**(4): 3172-3173.
- Patro, T.S.S.K., Raj Kumar, S., Meena, A., Anuradha, N., Triveni, U. and Joga Rao, P. 2019.** Screening for identification of resistant sources of barnyard millet varieties against sheath blight caused by *Rhizoctonia solani* Kuhn. *Int. J. Chem. Stud.* **7**(6): 957-959.
- Prakash, R. and Vanniarajan, C. 2015.** Path analysis for grain yield in barnyard millet (*Echinochloa frumentacea* (Roxb.) link). *Bangladesh J. Bot.* **44**(1): 147-150.
- Raju, P., Chockalingam, V., Vetriventhan, M., Gnanamalar, R.P., Shanmughasundaram, R. and Ramalingam, J. 2022.** Genetic variability of early flowering and yield contributing traits in Barnyard Millet [*Echinochloa frumentacea* (Roxb). Link] grown at different altitudes. *Indian J. Exp. Biol.* **60**(02): 131-136.
- Ramesh, G. V., Palanna, K. B., Vinaykumar, H. D., Kumar, A., Koti, P. S., Mahesha, H. S., Nagaraja, T. E., Tonapi, V. A., and Jeevan, B. (2021).** Occurrence and characterization of *Bipolaris setariae* associated with leaf blight of browntop millet (*Brachiaria ramosa*) in India. *J. Phytopathol.* **00**: 1–10.
- Ramesh, G.V., Palanna, K.B., Praveen, B., Vinay Kumar, H.D., Koti, P.S., Sonavane, P.**

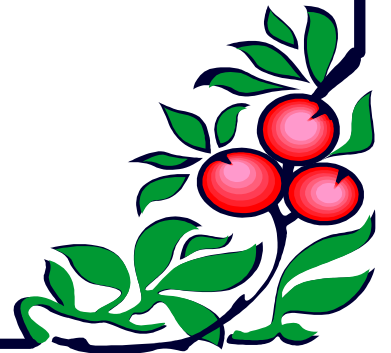
- and Tonapi, V.A. 2021.** First confirmed report of leaf blight on browntop millet caused by *Bipolaris setariae* in southern peninsular India. *Plant Dis.* **105**(05): 1561.
- Ranjan, R. 2015.** Climatic variability and trend at ranichauri (uttarakhand). *J. Agric. Meteorol.* **17**(2): 24-243.
- Ranjana, A. S. Jeena, Ankit Kumar and Rohit. 2020.** Genetic Analysis of Barnyard Millet (*Echinochloa frumentacea* (Roxb.) Link) Germplasm Collected from Uttarakhand Hills for Morphological Traits. *Int. J. Curr. Microbiol. App. Sci.* **9**(3): 1001-1010.
- Rao D.B., Bhaskaracharya, K., Arlene Christina G.D., Sudha Devi G., Vilas and Tonapi, A. 2017.** Nutritional and health benefits of millets. ICAR Indian Institute of Millets Research (IIMR) Rajendranagar, Hyderabad. 1-112.
- Rawat, L., Akanshu., Chauhan, S., Bahuguna, P., Tariyal, A. And Mamgain, A. 2022.** Effective management strategies for sheath blight disease of barnyard millet (*Echinochloa crusgalli* L.) incited by *Rhizoctonia solani* in hills of Uttarakhand. *Pantnagar J. Res.* **20**(2): 1-17.
- Rawat, L., Prasad, S. and Bisht, T.S., 2020.** Evaluation of barnyard millet advance line for yield, yield contributing traits and grain smut disease at high hills of Uttarakhand, India. *Int. J. Curr. Microbiol. Appl. Sci.* **9**(4): 387-394.
- Rehman, A.U., Naqvi, S.A., Umar, U.U. and Ahmed, R. 2017.** Evaluation of Various Wheat Lines Against Loose Smut (*Ustilago Tritici*) and its Epidemiological Studies. *Pak. J. Phytopathol.* **29**(02): 219-225.
- Samantha, S., Maitra, S., Shankar, T., Gaikwad, D., Sagar, L., Panda, M. and Samui, S. 2022.** Comparative performance of foliar application of urea and nano urea on finger millet (*Eleusine coracana* L. Gaertn). *Crop Res.* **57**(3): 166-170.
- Sangappa., Rafi. D. K and Srinivasa K.B. 2023.** A Study on Area-Production-Productivity of Minor Millets in India. *BFIJ.* **15**(1): 275-280.
- Sao, A., Singh, P., Kumar, P. and Pradhan, A. 2017.** Estimates of genetic parameters for yield and contributing traits in kodo millet (*Paspalum scrobiculatum* L.). *Res. J. Agric. Sci.* **8**(1): 120-122.
- Singamsetti, A., Patro, T.S.S.K., Anuradha, N. and Divya, M. 2018.** Studies on genetic variability for yield and yield attributing traits in finger millet (*Eleusine coracana* L. Gaertn). *Int. J. Curr. Microbiol. Appl. Sci.* **7**: 90-95.

- Singh, C. 1983.** Modern techniques of raising field crops. New Delhi, *Oxford and IBH publishing*. 1-565p.
- Singh, P. and Narayanan, S.S. 1993.** Biometrical techniques in plant breeding. Kayani Publishers, New Delhi. 1-182.
- Sood, S., Khulbe, R.K., Gupta, A.K., Agrawal, P.K., Upadhyaya, H.D. and Bhatt, J. C. 2015.** Barnyard millet—a potential food and feed crop of future. *Plant Breed.* **134**(2): 135-147.
- Thakur, S.R and Saini, J. P. 1995.** Variation association and path analysis in finger millet (*Eleusine coracana* (L.) Gaertn) under aerial moisture stress condition. *Indian J. Agri. Sci.* **65**(1): 54-57.
- Tripathi, S., Jain, A. and Kumar, A. 2016.** Effect of head smut on morphology and growth parameters of kodo millet (*Paspalum scrobiculatum* L.) cultivars. *Indian Plant Pathol.* **69**(4): 186-191.
- Trivedi, A.K., Arya, L., Verma, S.K., Tyagi, R.K. and Hemantaranjan, A. 2017.** Evaluation of barnyard millet diversity in central Himalayan region for environmental stress tolerance. *J. Agric. Sci.* **155**(10): 1497-150.
- Ulaganathan, V. and Nirmalakumari A. 2014.** Genetic variability and correlation studies for quantitative traits in finger millet [*Eleusine coracana* (L.) Gaertn] germplasm. *Int. Quarterly Jour. Of Enviro. Sci.* **5**(6): 21-25.
- Upadhyaya, H., Dwivedi, S.L., Singh, S.K., Sube, S., Vetriventhan, M. and Sharma, S. 2014.** Forming core collections in barnyard, kodo, and little millets using morpho agronomic descriptors. *Crop Sci.* **54**(6): 2673–2682.
- Upadhyaya, H.D., Gowda, C.L.L. and Reddy, V.G. 2007.** Morphological diversity in finger millet germplasm introduced from Southern and Eastern Africa. *J. SAT. Agric. Res.* **3**(1): 1-3.
- Upamanya, G.K., Brahma, R., Choudhury, M., Deka, P. and Sarma, R. 2019.** Response of different varieties of finger millet against diseases and evaluation of efficacy of fungicides against leaf blast. *Int. J. Recent Sci. Res.* **10**: 36655-36658.
- Vikram, S., Sudhagar, R., Masilamani, P. and Vanniarajan, C. 2020.** Genetic variability and association analysis in barnyard millet mutants. *Electron. J. Plant Breed.* **11**(01): 210-216.

- Vimalan, B., Thiyageshwari, S., Balakrishnan, K., Rathinasamy, A. and Kumutha, K. 2019.** Influence of NPK fertilizers on yield and uptake of barnyard millet grain (*Echinochloa frumentacea* (Roxb.) Link) in typic Rhodustalf soil. *J. pharmacogn. Phytochem.* **8**(2). 1164-1166.
- Waller, J.M. 1969.** Sugarcane smut (*Ustilago scitaminea*) in Kenya: I. Epidemiology. *Trans. Br. Mycol. Soc.* **52**(1):139-151.
- Yadav, M.S. and Duhan, J.C. 1993.** Prevalence and severity of smut disease in pearl millet growing belt of Haryana. *Crop Research (Hisar)*. **6**(3): 517-519.
- Yadav, O.P. and Rai, K.N. 2013.** Genetic improvement of pearl millet in India. *Agri. Res.* **2**(4): 275-292.
- Yadav, R. and Yadav, V.K. 2013.** Comparative performance of Indian and Japanese barnyard millet cultivars under varied fertility conditions for dual use in Indian Central Himalaya. *Range Manag. Agrofor.* **34**(2): 175-178.
- Yadava, H. And Jain, A. 2002.** Assessment of yield losses due to grain smut in barnyard millet. *Indian Phytopathol.* **50**(1): 49-52.
- Yenagi, N.B., Handigol, J.A., Ravi, S.B., Mal, B. and Padulosi, S. 2010.** Nutritional and technological advancements in the promotion of ethnic and novel foods using the genetic diversity of minor millets in India. *Indian J. Genet. Plant Breed.* **23**(1): 82-8



APPENDICES



APPENDICES

Appendix-I: Metrological data of Collge of Forestry, Ranichauri during *Kharif*-2022

Month	Tem. Max. (°C)	Tem. Min. (°C)	RH morning (%)	Rainfall (cm)	No. of rainy days	Sun Shine hrs.
May	25.16	10.96	68.33	20.56	2	9
June	26.1	13.25	73.75	30.95	2	7.85
July	24.25	14.15	94.25	74.65	4.5	5.27
August	24	13.92	94.75	80.67	2.75	5.1
September	22.6	12.46	93	45.88	2.4	4.78
October	20.65	7.45	78.5	3.45	0.5	7.37
November	17.93	4.33	81.33	1.06	0.33	7.7

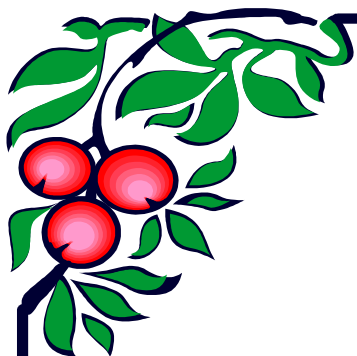
Source: Department of Agrometeorology, College of Forestry, Ranichauri Campus,
Tehri Garhwal, Uttarakhand

Appendix-II: Analysis of variance (ANOVA) for evaluation of 54 barnyard millet germplasm on days to 50% flowering, days to maturity, plant height, number of basal tillers, number of productive tillers and panicle length.

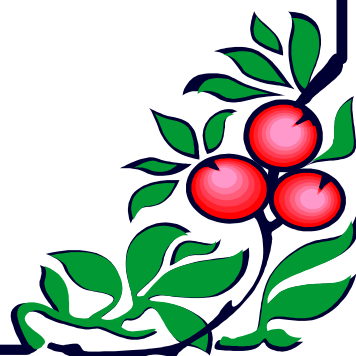
Mean sum of square							
Source of variation	Degree of freedom	Days to 50% flowering	Days to maturity	Plant height	Basal tillers	Productive tillers	Panicle length
Replication (r)	2	3.370	1.027	0.967	2.228	0.246	0.482
Treatment (t)	53	105.79**	59.58**	145.89 **	.298**	0.962**	50.099**
Error	106	1.263	1.609	8.749	0.294	0.287	0.466
C.V.		1.48	0.88	2.12	8.30	23.01	4.29
C.D. 5%		1.81	2.05	4.78	0.87	0.86	1.10
C.D. 1%		2.40	2.71	6.33	1.16	1.14	1.46

Appendix-II: Analysis of variance (ANOVA) for evaluation of 54 barnyard millet germplasm on panicle weight, grain yield, fodder yield, 1000 seed weight, seed length, seed width, biological yield and harvest index.

Mean sum of square									
Source of variation	Degree of freedom	Panicle weight	Grain yield	Fodder yield	1000 seed weight	Seed length	Seed width	Biological yield	Harvest index
Replication (r)	2	2.042	373006.2	1569.185	0.237	0.429	0.188	448663.7	58.244
Treatment (t)	53	35.305* *	77331.32* *	737001.4**	0.584**	0.111**	0.950**	752317.9**	29.281**
Error	106	5.716	29446.98	12513.60	0.996	0.324	0.541	45842.08	4.871
C.V.		12.51	10.69	2.68	3.19	2.09	3.82	3.71	7.91
C.D. 5%		3.87	277.79	181.087	0.16	0.922	0.119	346.60	3.57
C.D. 1%		5.12	367.53	239.593	0.21	0.122	0.157	458.58	4.72



ABSTRACT



ABSTRACT

Name: Neelam Pavan Kumar
Degree: M.Sc. Agriculture
Year of Admission: 2021
Department: Seed Science and Technology
College: College of Forestry

ID No: UUHF/21321
Major: Seed Science and Technology
Advisor: Dr. Laxmi Rawat
(Assistant Professor, Plant Pathology)

Topic: Evaluation of barnyard millet germplasm for morpho-metric characterization and screening against important endemic diseases in mid-hills of Uttarakhand

The present investigation was conducted during *Kharif*-2022 at Plant Pathology Research Block, College of Forestry, Ranichauri, Tehri Garhwal, V.C.S.G Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal. Fifty-four germplasm lines of barnyard millet were sown in randomized block design. Observations were recorded for morphometric traits, disease severity and seed attributing traits during the investigation. The qualitative traits *viz.*, panicle compactness, inflorescence colour and inflorescence shape shows a wide range of variation. Results for quantitative traits showed more than 80 percent heritability along with moderate to high genetic advance except for number of basal tillers. The values for genotypic coefficient of variation and phenotypic coefficient of variation were almost similar indicating the less influence of environment on studied traits however, genotypic coefficient of variation was slightly higher than phenotypic coefficient of variation. Significant variation was recorded in seed attributing traits. Seed attributing traits *viz.*, seed length and seed width had high heritability. Out of fifty-four germplasm, two germplasm lines *viz.*, BM-1 and BM-34 were identified as immune to all the endemic diseases under study. Thirty-four germplasm lines were found highly resistant (HR) and six germplasm lines were found moderate resistant (MR) to grain smut. In case of sheath blight, fourteen germplasm lines were found resistant (R) and remaining germplasm were found to be moderately resistant (MR). All the germplasm lines were found resistant (R) to leaf blight disease and results of head smut screening showed that two germplasm lines were found resistant (R) and the remaining germplasm lines were found to be highly immune.

From the present investigation, two germplasm *i.e.*, BM-1 and BM-34 were identified as superior genotypes for better growth and yield related traits such as grain and fodder yield as well as were found to be resistant against all the diseases under study. Hence, these two identified germplasm are concluded to be of great values and might further be used for crop improvement programme in developing high yielding diseases resistant varieties of barnyard millet.



(Dr. Laxmi Rawat)
Advisor



Neelam Pavan Kumar
(Author)

सारांश

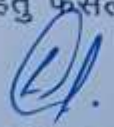
नाम— नीलम पवन कुमार
उपाधि— स्नातकोत्तर (कृषि)
प्रौद्योगिकी
सत्र एवं प्रवेश वर्ष— 2021

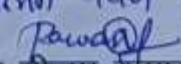
परिचय संख्या— 21321
मुख्य विषय— बीज विज्ञान एवं
सलाहाकार— डॉ० लक्ष्मी रावत
(सहायक प्राध्यापक, पादप रोग विज्ञान)

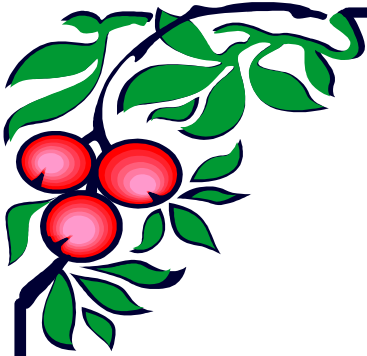
विषय — झंगोरे के जननद्रव्यों का मॉर्फो-मीट्रिक लक्षणों और प्रमुख स्थानिक रोगों के खिलाफ जाँच के लिए उत्तराखंड के मध्य-पर्वतीय क्षेत्रों में मूल्यांकन।

वर्तमान शोध कार्य वीर चन्द्र सिंह गढ़वाली उत्तराखंड औद्यानिकी एवं वानिकी विश्वविद्यालय भरसार, वानिकी महाविद्यालय, रानीचौरी, टिहरी गढ़वाल के पादप रोग विज्ञान शोध प्रक्षेत्र में खरीफ-2022 के दौरान किया गया था, जिसमें झंगोरे की चौवन जननद्रव्यों की लाइनों को रैंडमाइज्ड ब्लॉक डिजाइन में लगाया गया था। शोध के दौरान रूपमिति लक्षण, रोग की गंभीरता और बीजों के लक्षण के लिए अवलोकन दर्ज किए गए। गुणात्मक लक्षण जैसे, पुष्पगुच्छ की सघनता, पुष्पक्रम का रंग और पुष्पक्रम का आकार विविधता की एक विस्तृत श्रृंखला को दर्शाता है। मात्रात्मक लक्षणों के परिणामों में बेसल टिलर्स की संख्या को छोड़कर मध्यम से उच्च आनुवंशिक उन्नति के साथ-साथ 80 प्रतिशत से अधिक आनुवंशिकता देखी गई। भिन्नता के जीनोटाइपिक गुणांक और भिन्नता के फेनोटाइपिक गुणांक के मान लगभग समान थे जो अध्ययन किए गए लक्षणों पर पर्यावरण के कम प्रभाव को दर्शाता है, हालांकि, भिन्नता का जीनोटाइपिक गुणांक फेनोटाइपिक भिन्नता गुणांक से थोड़ा अधिक पाया गया। बीज के गुणों में महत्वपूर्ण भिन्नता दर्ज की गई। बीज के गुणों जैसे बीज की लंबाई और बीज की चौड़ाई में उच्च आनुवंशिकता थी। चौवन जननद्रव्यों में से, दो जननद्रव्य लाइनें अर्थात् BM-1 और BM-34 को अध्ययन के तहत सभी स्थानिक रोगों के प्रति प्रतिरोधी के रूप में पहचाना गया। चौतीस जननद्रव्य लाइनें अत्यधिक प्रतिरोधी पाई गईं और छह जननद्रव्य लाइनें दाने का कण्ड रोग के लिए मध्यम प्रतिरोधी पाई गईं। पर्णछद अंगमारी रोग के मामले में, चौदह जननद्रव्य लाइनें प्रतिरोधी पाई गईं और शेष जननद्रव्य मध्यम प्रतिरोधी पाए गए। सभी जननद्रव्य लाइनें पर्णछद अंगमारी रोग के प्रति प्रतिरोधी पाई गईं और शीर्ष कण्ड रोग की जाँच के नतीजों के परिणामस्वरूप, दो जननद्रव्य लाइनें BM-18 और BM-24 प्रतिरोधी पाई गईं और शेष जननद्रव्य लाइनें अत्यधिक प्रतिरोधी पाई गईं।

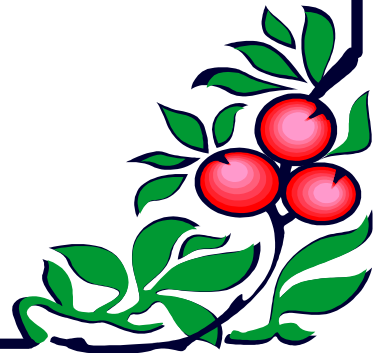
वर्तमान शोध कार्य से, दो जननद्रव्यों BM-1 और BM-34 को बेहतर विकास, उपज संबंधी लक्षणों के लिए बेहतर जीनोटाइप के रूप में पहचाना गया और साथ ही अध्ययन के तहत सभी बीमारियों के खिलाफ प्रतिरोधी पाया गया। इसलिए, इन दो पहचाने गए जननद्रव्यों को प्रमुख मूल्यों के रूप में निष्कर्ष निकाला गया है और भविष्य में झंगोरे की उच्च उपज एवं रोग प्रतिरोधी किस्मों को विकसित करने हेतु फसल सुधार कार्यों के लिए उपयोग किया जा सकता है।


डॉ० लक्ष्मी रावत
(सलाहाकार)

नीलम पवन कुमार

पवन नीलम कुमार
(लेखक)



VITAE



VITAE

The author was born on 11th April, 1998 at Suryapet, Telangana. He passed his Intermediate Examination in 2016 from SRI MEDHA JUNIOR COLLEGE, Hyderabad. In 2020, he did his graduation in B.Sc. (Agriculture) from SURESH GYAN VIHAR UNIVERSITY, Rajasthan. He joined V.C.S.G. Uttarakhand University of Horticulture and Forestry, Bharsar in 2021 for the degree of M.Sc. (Ag.) Seed Science and Technology.

Permanent Address:

Neelam Pavan Kumar

S/o: Mr. Neelam Yadagiri

House No- 5-5/28/59/51, Bolligudem, Boduppal

Medipally Mandal, Medchal District, Hyderabad-500098

Telangana.

E-mail: neelampavankumarp@gmail.com