Evaluation of Proso Millet (P*anicummiliaceum* L.) Germplasm for Yield and Related Traits in Godawari Municipality, Kailali, Nepal [1]

Sanjay Kumar Raut, Rakshya Sharma, Ritambar Ghimire, Devraj Rajbanshi, & Binod Bohara

Abstract

Proso millet (*Panicummiliaceum*L.), a short-duration C4 plant, is sparsely grown in mid hills of Karnali and Far western province during summer and rainy season. This crop has hugepotential for enhancing the food security in Nepal. To explore its suitability as a catch crop after wheat harvest in Terai, a field experiment was carried out considering 6 genotypes and 2 local varieties from Bajura, at Godawari municipality-8, Kailali. The experiment employed a randomized complete block design with 8 treatments and three replications. Data on plant height, panicle count/m^2, panicle length, grain yield, straw yield, days to panicle emergence and maturity were analyzed and treatment means were compared at 5% level of significance. Results showed significant variation in growth, yield and yield attributes among the genotypes and varieties. Malchino exhibited smallest height, highest number of panicles/m^2, smallest panicle, lightest seed, lowest grain sterility and short period to panicle emergence and maturity. Hence, Malchino yielded 3 times more grains and 2 times less straw than Dudhe chino, another popular variety from Bajura. Straw yield was significantly lower in Malchino, followed by NGRCO 7346, NGRCO7340, and Dudhe chino. NGRCO7339 produced significantly higher yield, revealing its potential to be grown as fodder crop in terai region. A significant positive association (r=0.96) between grain yield and harvest index, indicating that higher harvest index tend to produce higher yields, while an inverse correlation (r = -0.94) between

[1] Cite this article as: Raut, S. K. et al. (2024). *Contemporary Research: An Interdisciplinary Academic Journal*, vol. 7 (2); DOI: https://doi.org/10.3126/craiaj.v7i2.72169

Sanjay Kumar Raut, Rakshya Sharma, Ritambar Ghimire, Devraj Rajbanshi, & Binod Bohara, faculties of Agriculture, Far Western University, Tikapur, Kailali, Nepal.

Email: sanjayraut309@gmail.com, sanjay.raut@fwu.edu.np

Article history: Received on August 31, 2024; Accepted on Nov. 14, 2024; Published on Nov. 28, 2024

Peer reviewed under the authority of CRAIAJ, academic journal of Ghodaghodi Multiple Campus, Kailali, Nepal, with ISSN 2717-4611 (Print) and ISSN 2717-462X (Online).

grain sterility and grain yield suggested that lowering grain sterility could improve yield. The genetic analysis showed strong heritability and advancement for grain yield, highlighting its potential as a drought tolerant crop. The results also revealed that proso millet, a short cycle crop, is suitable for cultivation during the fallow period between two cropping season. The finding also suggests that further research needed to be conducted on date of planting to reduce grain sterility.

***Keywords*:** Dudhe Chino, Genetic variability, Grain sterility, Heritability, Malchino

Background

Millet crops distribution across world among them Proso millet (*Panicummiliaceum* L.) is a C_4 short-duration important indigenous small seeded cereal crop belongs to Poaceae family with big potential. Proso millet is tetraploid (2n=4x=36) species. It is commonly known as bird seed, broomcorn millet, hog millet, white millet, yellow millet, or common millet. Around 10,000 years ago it is believed to be domesticated (Rajasekaran et al., 2023). It is widely cultivated in Hindu Kush Himalayan region countries *i.e.* India, Burma, Sri lanka, Pakistan, Nepal and south eastern countries (Joshi et al., 2023).The plant characteristics that set unique in that the seed husk (palea and lemma) stay attached to seedling roots. The inflorescence of Proso millet is compact, drooping in nature that is 4–18 inch (10–45 cm) long. The inflorescence is made up of many ovoid, stalked spikelets (Sheahan, 2014).

In Nepal, proso millet (Chino) is the second most important millet crop for food and nutrient security among a group of millets that have a wide range of culinary use such as boiled rice, Rice pudding (kheer), bread and traditional distilled alcoholic beverage (fermented raksi) (Ghimire et al., 2018). Proso-millet varieties have short growing cycle from sowing to harvest of 60–110 days (Habiyaremye et al., 2017). This crop can be grown in the tropical, subtropical and even at an altitude of 3500 masl (Ghimire et al., 2018). Under dry areas, the grain yield ranges from 500 to 700 kg per hectare, and under irrigated or ideal circumstances, it ranges from 1500 to 2000 kg per hectare (Tonapi et al., 2015).

In Nepal, proso millet's potential has not been fully realized; it can be serving as a catch crop. In plain area of far-western province less rainfall occurs due to this field remain fallow of many farmers. Proso millet offers the advantage of being an extra cash crop in a wheat- proso millet-fallow rotation. Proso millet is drought tolerance, and generally can be grown as catch crop in tropical region. (Baltensperger, 1996)

Proso millet is high yielding variety within a broad collection of millets crops reveals its significant role for food security. Not much study and research has been done on the neglected and underutilized crops, especially in tropical region. Prosomillet landraces have unique traits for both biotic and abiotic tolerance that can help to adapt crop in diverse terrains (Joshi et al., 2023, Kheya et al., 2023). Proso millet can tolerate temperature as high as 42 c and millet grain are 70% more water efficient than rice (Kheya et al., 2023).

As limited research has been conducted for selection of suitable prosomillet variety in Kailali condition, this field research has been conducted to find out the ability to adopt in tropical condition and with suitable variety for catch crop with better yield. The objective of this research was to analyze morphological traits and yield in proso millet germplasm through characterization and evaluation using agro-morphological data.

Materials and methods

Site selection and experimental material

The experiment was conducted in Far-western province, Kailali district at Godawari Municipality-8, Phakalpur, Nepal during March to May 2024. The research site lies in tropical agro-ecological belt around 200 masl. The research field had sandy clay loamsoil with soil pH 7.32. The field contains organic matter (0.71), available Nitrogen (0.04%), Phosphorus (12.58%) and Potassium (88.15%) with good water holding capacity of 52.34.

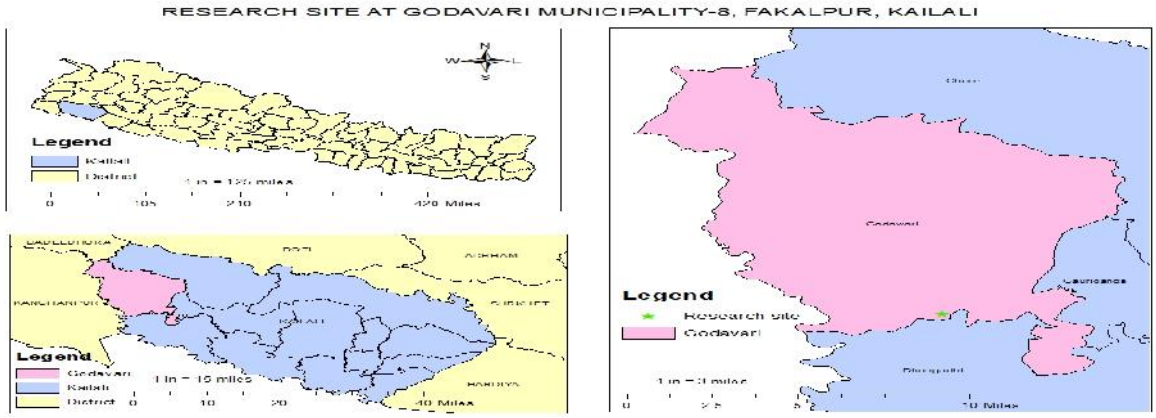

Figure 1 *Research site*

Treatment source

A total of eight proso millet accessions collected for the varietal characterization. Among them, six accessions (NGRCO 7338, NGRCO 7339, NGRCO 7340,NGRCO 7341,NGRCO 7342and NGRCO 7346) were collected from National Agriculture Genetic Resources Centre, Lalitpur and two accessions (Dudhe Chino and Mal Chino) were collected from farmers ofBajura district. Whereas,dudhe chino was used as check variety.

Experimental design

The experiment comprised as single factor with Random complete block design (RCBD) design with three replication and eight treatments. Individual plot size: 3 m^2 (2m×1.5m), maintaining 1m distance betweenreplications. Total experiment area: 182.75 m^2 (21.5 m×8.5m).

Cultural practices

The land was initially plowed using a power tiller as primary tillage on 9th February 2024. FYM was applied @ 12.5 t/ha and ploughed into soil as secondary tillage. Crop residue, weeds were removed and make fine soil before seed sowing.The seeds were sown continuous at about3.0 cm deep on rows with inter row spacing of 25 cm on 9th March 2024 followed by thinning after one week.

Data collected

Data were recorded on ten randomly selected plantsin each plot in each replication and their average value was calculated for agro-morphological and yield attributing traits.

Days to 50% panicle emergence

Days to 50% panicle emergence, days were recorded by observing each plot, when around 50% of seed germinated then data was recordedand number of days was calculated from the date of sowing.

Plant height (cm)

The height of plant was measured from the base of the plant above the ground level to the tip of the plant at the time of harvest using measuring scale and mean value of sample plant were expressed in centimeter.

Number of tiller per m^2

Total number of productive effective and nonproductive tiller were counted using quadrate before harvesting.

Panicle length

The panicle length was measured from node using measuring scale from 10 sample plants and mean value was expressed in centimeter

Days to maturity

When 100% plants of individual genotype got ready to harvest, date was recorded, and number of days was calculated from the date of sowing.

Grain sterility per panicle

Grain sterility was calculated based on number of empty sink present and number of filled sink.

Yield (kg/ha)

The yield was calculated using formula for hectare.

(Grainyield(kg/ha)=(plotyield(kg)x10,000)/plotsizeinsquare meters)

Harvest index

Harvest index was used to express the efficiency of plant in allocating its economic output to harvestable part.

Harvest Index=Biological Yield/Economic Yield

Statistical analysis

Analysis for mean and standard deviation, Genetic parameters was done by using R studio (4.3.3). Analysis of Variance (ANOVA) was used to assess genotypic effect and check if the mean of two or more treatments significantly different from each other by the least significant difference (LSD) test at 5% level of significance. Correlations and genetic parameter between important traits were evaluated.

Results and discussion

Plant height and effective tillers

Among eight varieties evaluated, the taller plant was recorded in NGRCO 7339 followed by NGRCO 7338, with significant differences between them. While shorter plant was produced by Malchino. The pooled data showed that NGRCO 7339, NGRCRO 7338, NGRCO 7341 and NGRCO 7342 varieties were significantly superior over other varieties with respect to plant height (Table 1). Rajasekaranet al.(2023), indicate thatprosomillet plant height range from 45 to 130 cm. This result is accordance with Khatun et al.(2023) found significant differences in plant 97 germplasm. Similarly, Singode et al.(2023), while evaluating 634 germplasm of prosomillet found significant

difference in plant height at the altitude of 476.5 masl. This result is also accordance with salineet al.(2010).

Productive tiller/ m^2

The result indicated a significant variability in number of productive tiller /m^2 among the tested varieties. Mal chino recorded significantly higher number of productive tiller /m^2 among the other tested varieties. While least number of effective tiller/m^2 plants was produced by NGRCO 73340.

Nonproductive tiller/m^2

Among the tested germplasm total number of nonproductive tiller (Sterile tiller) were significantly influenced by the varieties. NGRCO 73340 showed maximum nonproductive tiller among tested varieties. While, Malchino showed lessnumber of nonproductive tiller followed by dudhe chino, NGRCO 7346 and NGRCO 7338.

Table 1

Plant height and productive and nonproductive tillers of proso millet genotypes

Treatments	Plant height (cm)	Productive tillers/m^2	Nonproductive tillers/m^2
NGRCO 7338	111.90^{ab}	141.00c	9.82b
NGRCO 7339	120.86^{a}	157.33c	12.10ab
NGRCO 7340	102.60^{b}	91.00d	18.13a
NGRCO 7341	111.60^{ab}	125.00c	10.97ab
NGRCO 7342	106.83^{ab}	147.67c	10.99ab
NGRCO 7346	72.93^{cd}	205.67b	6.11b
Dudhe chino	86.93^{c}	194.33b	5.08b
Mal chino	66.36^{d}	251.33a	4.81b
$LSD_{0.05}$	14.13	32.34	6.9
SEm(±)	4.66	10.66	2.27
F test	***	***	*
P value	5.24e-^{06}	1.33e-^{06}	0.015
CV (%)	8.27	11.25	40.44
Grand mean	97.05	164.16	9.75

Days to panicle emergence

The genotypes showed significant differences for days to 50% panicle emergence for each treatment. NGRCO 7346 needed less day for days to panicle emergence followed by dudhe chino and Malchino (Table2). This difference is due to genetic composition of genotypes not only due to environment. This finding was in accordance with Joshi et al. (2023).

Days to maturity

The days to maturity shows highly significant differences among the varieties under consideration. Among the tested varieties Malchino mature earlier due to its fast vegetative growth followed by dudhe chino and NGRCO7346.Days to maturity are one of the important indicators to assess the variability of germplasm. The research conducted sixteen meter above sea level to four hundred seventy meter above sea level also indicated variability in days to maturity. So, this finding was correlated with Khan et al.(2023), Vetriventhan & Upadhyaya(2018), Elangovan et al.(2023), Joshi et al.(2023).

Table 2

Phenological traits of Proso millet genotypes

Treatments	Days to panicle emergence	Days to maturity
NGRCO 7338	51.00^{b}	72.33^{a}
NGRCO 7339	51.33^{b}	73.00^{a}
NGRCO 7340	51.33^{b}	73.66^{a}
NGRCO 7341	49.67^{c}	73.66^{a}
NGRCO 7342	52.67^{a}	73.66^{a}
NGRCO 7346	37.67^{d}	69.00^{b}
Dudhe chino	38.33^{d}	68.66^{b}
Mal chino	38.33^{d}	62.66^{c}
$LSD_{0.05}$	0.82	2.08
SEm(±)	0.27	0.68
F test	***	***
P value	$2.20e^{-16}$	$1.49e^{-07}$
CV(%)	1.01	1.68
Grand mean	46.29	70.83

The agro morphological traits were highly significant for panicle length, filled grain per panicle and thousand grain weights. Similarly, grain sterility was also found significant among the tested germplasm (Table 3).

Panicle length

The panicle length of proso millet was significantly influenced by variety. The panicle length varied from 21.10 to 37.53 cm. The result indicated that the longest panicle length was observed in NGRCO 7341. The shortest panicle length was observed in Mal chino. Khatun et al. (2023) conducted research 16 masl with 97 germplasm also found significant difference in length of panicle. This result is also accordance with Elangovan et al. (2023).

Filled grain per panicle

The number of filled grain varied from 124 to 243. When panicle sink was counted in sample plant, highest number of filled grain was obtained in NGRCO 7341 and least number of filled grains was obtained in Dudhe chino. The increase in number of filled grain per plant increase economic yield. The result of Elangovan et al.(2023) also found significant difference for grain per plant; his result is accordance with analysis of variance result in table 3.

Grain sterility per panicle

It was observed that grain sterility was varied from 35.30 to 69.81 percentages. Lowest number of grain sterility was observed in Malchino and highest number of sterility was observed in NGRCO 7342.

Thousand grain weight(g)

Thousand grain weights varied from 3.39 to 5.07 g,highest thousand grain weights was observed in NGRCO 7338 due to bold and large seed size and lowest weight was observed in mal chino due to its seed size. The result of analysis of variance shows highly significant difference for thousand grain weight. This result is supported by Khatun et al.(2023), Elangovan et al.(2023), Salini et al. (2010), Joshi et al.(2023).

Table 3

Yield attributing traits of Proso millet genotypes

Treatments	Panicle length (cm)	Filled grain per panicle	Grain sterility (%)	Thousand grain weight (g)
NGRCO 7338	37.20^{a}	235.53^{ab}	57.81^{b}	5.07^{a}
NGRCO 7339	36.06^{a}	170.33^{cd}	67.62^{a}	4.65^{c}
NGRCO 7340	36.77^{a}	190.40^{b-d}	65.96^{ab}	4.45^{e}
NGRCO 7341	37.53^{a}	242.53^{a}	62.00^{ab}	4.82^{b}
NGRCO 7342	34.56^{a}	123.90^{e}	69.81^{a}	4.59^{cd}
NGRCO 7346	28.06^{b}	146.40^{de}	57.61^{b}	4.50^{de}
Dudhe chino (check variety)	30.93^{b}	118.40^{e}	69.30^{a}	4.55^{c-e}
Mal chino	21.10^{c}	194.50^{bc}	35.30^{c}	3.39^{f}
$LSD_{0.05}$	2.91	43.81	8.39	0.10
SEm(±)	0.96	14.44	2.76	0.035
F test	***	***	***	***
P value	$6.63e^{-08}$	0.00012	$8.36e^{-06}$	$8.10e^{-13}$

CV(%)	5.08	14.07	7.89	1.36
Grand mean	32.77	177.75	60.68	4.50

Grain yield (t/ha)

A wide significant variation was observed for grain yield in Table 4. The highest grain (economic yield) was recorded in mal chino while low yield was obtained from NGRCO 7342.Anuradha et al.(2020) reported differences among 20 prosomillet accessions for grain yield. This result is also supported by Saliniet. al. (2010), Adhikari et al. (2018), Vetriventhan & Upadhyaya (2018), Khatunet al. (2023), Elangovan et al.(2023),Joshi et al.(2023).

Straw yield (t/ha)

Straw yield varied from 14.10 to 4.30 t/ha. Highest straw yield was measured in NGRCO7339 and mal chino have low straw yield. Prosomillet crop can be utilized for both grain and fodder, The straw is used as quality forage for livestock is becoming increasingly important for livestock farming. This result is accordance withBhat et al. (2019), Anuradha et al. (2020), Joshi et al.(2023), Rajasekaran et al. (2023).

Harvest index

The prosomillet genotypes showed significant differences on harvest index, which ranged from 0.03 to 0.28. The highest harvest index was found in Malchino while lowest was found in NGRCO 7338 and NGRCO 7339.

Table 4

Grain yield and straw yield of Proso millet genotypes

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index
NGRCO 7338	0.47^{b}	12.52^{a}	0.03^{d}
NGRCO 7339	0.49^{b}	14.10^{a}	0.03^{d}
NGRCO 7340	0.43^{b}	7.80^{b}	0.05^{c}
NGRCO 7341	0.41^{b}	11.05^{a}	0.03^{d}
NGRCO 7342	0.40^{b}	12.39^{a}	0.03^{d}
NGRCO 7346	0.55^{b}	5.84^{bc}	0.08^{b}
Dudhe chino	0.54^{b}	8.09^{b}	0.06^{c}
Mal chino	1.67^{a}	4.30^{c}	0.28^{a}
$LSD_{0.05}$	0.19	2.91	0.01
SEm(±)	0.063	0.96	0.0039
F test	***	***	***
P value	$1.49e^{-08}$	$3.19e^{-05}$	$1.79e^{-15}$
CV (%)	17.61	17.49	8.69
Grand mean	0.62	0.96	0.077

Correlation study

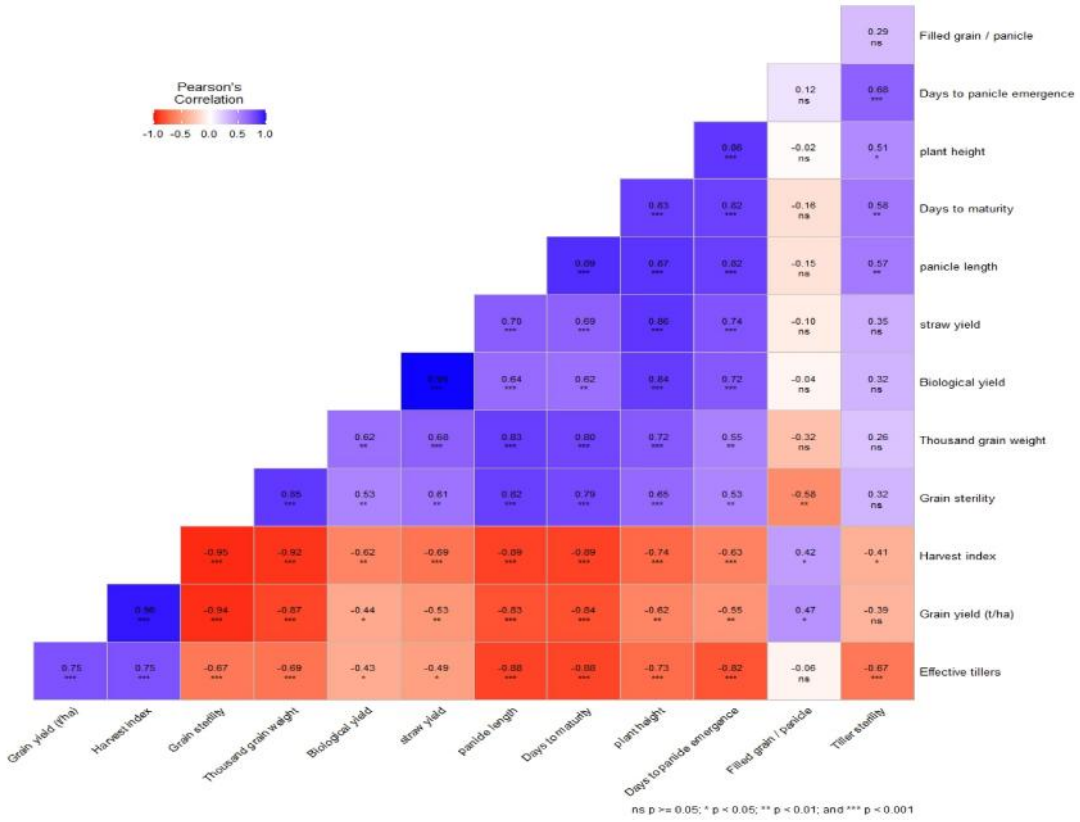

Figure 1: *Correlation matrix among different traits for eight prosomillet genotypes*

In figure 1, the correlation coefficient value of harvest index and grain yield (t/ha) is 0.96, indicating a very strong positive relationship among traits. In case of plant height and panicle length, it is 0.86 and among grain sterility and grain yield, it is 0.75 showing strong positive relationship.

Moderate positive correlation is found between days to maturity and plant height (0.58) followed by days to panicle emergence and plant height (0.51). The result also revealed negative correlation among the traits. Grain sterility and grain yield (t/ha) showed a strong negative correlation with correlation coefficient of -0.94. It was found

that both the variables move in opposite direction i.e., when grain sterility increases grain yield decreases and vice versa.

When we observe key traits like grain yield (t/ha), it is strongly positively correlated with harvest index (0.96). Similarly, harvest index also showed strong positive correlation with grain yield (0.96). Grain sterility indicated negatively correlated with effective tillers and grain yield, which implies that higher grain sterility results in lower grain yield and fewer numbers of effective tillers. This result is in accordance with Saliniet al. (2010).

Estimation of PCV, GCV, GA and H^2

Table 5

Genetic variability, heritability and genetic advance of quantitative traits

(GCV= genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, GA= Genetic advance, GAM= Genetic advance as percentage of mean, H^2_{bs} = Broad sense heritability)

Traits	**GCV (%)**	**PCV (%)**	**H^2_{bs}**	**GA**	**GAM (%)**
PH	19.76	21.42	0.85	36.60	37.53
PL	17.40	18.12	0.92	11.27	34.39
Filled grain/panicle	18.22	24.55	0.55	42.13	27.86
Grain sterility	21.61	22.90	0.89	26.94	42.01
Effective tillers	31.92	33.42	0.91	99.96	62.80
Tiller sterility	40.14	51.24	0.61	6.58	64.77
DPE	14.73	14.77	0.99	14.02	30.28
DM	5.40	5.66	0.91	7.52	10.62
Thousand grain weight	10.87	10.96	0.98	1.00	22.22
GY	67.68	69.94	0.94	0.84	134.94

The value of PCV obtained for yield and attributing characters ranged from 5.66 for days to maturity to 69.94 for grain yield. The value of GCV ranged from 5.40 for

days to maturity to 67.68 to grain yield. This result is in consonance with earlier studies of Anuradha et al. (2020) and Hawlader (1991). High broad sense heritability and high GAM were recorded for grain yield and effective tillers indicates preponderance of additive gene action and additive gene action is very much selection responsive.

Conclusion

The research findings indicate that there was notable variation among the eight proso millet cultivars assessed, namely in terms of plant height, tiller output, and grain yield. Mal chino was the most promising variety for producing grain and fodder since it had the best grain yield and the lowest sterility, but NGRCO 7339 and NGRCO 7338 demonstrated superior plant height. Similarly, days to plant maturity range from 62.66 to 73.66. Days to maturity make proso millet ideal catch crop. Additionally, the study showed a substantial negative link between grain sterility and yield and a large positive correlation between essential features such as grain yield and harvest index, suggesting that decreased sterility leads to higher grain production. Genetic component shows that grain yield and efficient tillers are important qualities, the study found significant genetic diversity and heritability, suggesting a great opportunity for selection and improvement through breeding. While, traits with significant genetic advance, such as grain yield, suggest that additive gene action plays a crucial role

Acknowledgements

We would like to extend our deepest gratitude to our donor “ICIMOD GRAPE FA2”, who has made our faculty research accomplishments this year possible. We are thankful to school of Agriculture for supporting during research period. We appreciate Mr. Laxman Chaudhary, the farmer who provided research field and students who supported during research period.

Reference

Adhikari, B.N., Pokhrel, B. B., & Shrestha, J. (2018). Evaluation and development of finger millet (*Eleusinecoracana* L.) genotypes for cultivation in high hills of Nepal. Farming and Management, 3(1), 37-46

Anuradha, N., Patro, T. S. S. K., Triveni, U., Rao, P. J., & Priya, P. K. (2020). Genetic variability studies of grain yield and its attributes in proso millet (Panicummiliaceum L.). *Int. j. curr.microbiol.appl. sci*, *11*, 1445-1449.

Baltensperger, D. D. (2002). "Progress with proso, pearl and other millets," in Trends in New Crops and New Uses, eds J. Janick and A. Whipkey (Alexandria: ASHS Press), 100–103.

Bhat, S., Nandini, C., Srinathareddy, S., &Jayarame, G. (2019).Proso millet (*Panicummiliaceum* L.)-a climate resilient crop for food and nutritional security: A Review. *Environment Conservation Journal*, *20*(3), 113-124.

Elangovan, M., Singode, A., Venkatesh, K., Amasiddha, B., Karthik, A. S., Pandey, S., &Pandey, C. D. (2023).Agro-morphological Characterization of Proso millet Germplasm for Utilization. *International Journal of Plant & Soil Science*, *35*(16), 381-392.

Habiyaremye, C., Barth, V., Highet, K., Coffey, T., & Murphy, K. M. (2017). Phenotypic responses of twenty diverse proso millet (*Panicummiliaceum* L.) accessions to irrigation. *Sustainability*, *9*(3), 389.

Hawlader, M. S. H. (1991). Genetic variability and correlation study in proso millet (Panicummiliaceum L.). *Ann. BangadeshAgri*, *1*(2), 61-64.

Ismail, T., Qamar, M., Khan, M., Rafique, S., &Arooj, A. (2023). Agricultural Biodiversity and Food Security: Opportunities and Challenges. *Neglected Plant Foods Of South Asia: Exploring and valorizing nature to feed hunger*, 1-27.

Joshi, B. K., Bhattarai, M., Bhusal, B., Sharma, S., KC, N., &Ghimire, K. H. (2023).Millet Genetic Resources and Diversity in Nepal.

Joshi, B.K., Shrestha, R.K., Ghimire, K.H., KC, H.B., and GC, A.(2023), eds. 2023.Millets traditions, science and technology in Nepal.NAGRC, CCDABC and FAO; Kathmandu, Nepal.

Khatun, M. F., Islam, M. S., Jahan, N., Ahmed, Q. M., Islam, M. R., &Pervin, N. (2023). MORPHOLOGICAL CHARACTERIZATION AND DIVERSITY ANALYSIS OF PROSO MILLET (Panicummiliaceum L.) GERMPLASM IN BANGLADESH. *International Journal of Agriculture and Environmental Research*, *9*(5), 750-765.

Kheya, S. A., Talukder, S. K., Datta, P., Yeasmin, S., Rashid, M. H., Hasan, A. K., ...& Islam, A. M. (2023). Millets: The future crops for the tropics-Status, challenges and future prospects. *Heliyon*.

Rajasekaran, R., Francis, N., Mani, V., & Ganesan, J. (2023).Proso millet (*Panicummiliaceum*L.).In *Neglected and underutilized crops* (pp. 247-278).Academic Press.

Saha, D., Gowda, M. C., Arya, L., Verma, M., & Bansal, K. C. (2016). Genetic and genomic resources of small millets. *Critical Reviews in Plant Sciences*, *35*(1), 56-79.

Salini, K., Nirmalakumari, A., Muthiah, A. R., &Senthil, N. (2010).Evaluation of proso millet (*Panicummiliaceum* L.) germplasm collections. *Electronic Journal of plant breeding*, *1*(4), 489-499.

Sheahan, C.M. 2014. Plant guide for proso millet (*Panicummiliaceum* L). USDA-Natural Resources

Singode, A., Chapke, RR, Sangappa.,Domathoti, B., Padmaja, PG, Bhat, VB, Malathi VM, Venkateswarlu, R., Dheeravathu SN, &Ratnavathi, CV (2023). Proso Millet: Importance and Cultivation. Indian Farming, 73(1), 110-111.

Tonapi, V. A., Bhat, B. V., Kannababu, N., Elangovan, M., Umakanth, A. V., Kulkarni, R., ... &Rao, T. G. N. (2015). *Millet seed technology: seed production, quality control & legal compliance*. Hyderabad, India: Indian Institute of Millets Research. Page:115-278

Vetriventhan, M., & Upadhyaya, H. D. (2018). Diversity and trait-specific sources for productivity and nutritional traits in the global proso millet (*Panicummiliaceum* L.) germplasm collection. *The Crop Journal*, *6*(5), 451-463.

Wimalasiri, E. M., Ashfold, M. J., Jahanshiri, E., Walker, S., Azam-Ali, S. N., &Karunaratne, A. S. (2023).Agro-climatic sensitivity analysis for sustainable crop diversification; the case of Proso millet (*Panicummiliaceum* L.). *Plos one*, *18*(3), e0283298.