AGROMORPHOLOGICAL CHARACTERISATION OF FOXTAIL MILLET (*Setaria italica* L. *Beauv*) AT RAMPUR, CHITWAN

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REQUIREMENTS FOR THE UNDERGRADUATE PRACTICUM ASSESSMENT COUSER OF

BACHELORS OF SCIENCE IN AGRICULTURE

MAY, 2016

CERTIFICATE

This is to certify that the thesis entitled "**AGROMORPHOLOGICAL CHARACTERISATION OF FOXTAIL MILLET (*Setaria italica* L. *Beauv*) AT RAMPUR, CHITWAN** " submitted in partial fulfillment of the requirements for the Undergraduate Practicum Assessment Course of "**Bachelors of Science in Agriculture**" of the Undergraduate Program, Institute of Agriculture and Animal Science, Rampur, is a record of original research carried out by **Mr. Dipak Timilsina, Mr. Manoj Sapkota, Mr. Mukesh Kumar Yadav and Ms. Sapana Ghimire**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma and is hereby accepted.

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

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Prof. Madhav Pandey, Ph.D.

Chairman of the Advisory Committee

Department of Genetics and Plant Breeding

Date:

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Institute of Agriculture and Animal Science

Date:

DEDICATED

TO

OUR BELOVED PARENTS,

TEACHERS, FRIENDS

AND

JUNIORS

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ABBREVIATION AND ACRONYM

%	percentage
ANOVA	Analysis of Variance
cm	centimeter
Co-	Collection number
CV	Coefficient of variation
Df	degrees of freedom
DMRT	Duncan's Multiple Range Test
EC	Emulsifiable Concentrate
gm	gram
ha	hectare
IBPGR	International Board for Plant Genetic Resources
kg	kilogram
l	liter
LSD	Least Significant Difference
masl	meters above sea level
mm	millimeter
Mt	metric tons
NGRC	National Genetic Resource Centre
NMRP	National Maize Research Program
^{o}C	degree Celsius
PCA	Principal Component Analysis
RCBD	Randomized Complete Block Design
UPGMA	Unweighted Paired Group Method using Arithmetic Averages
USDA	United States Department of Agriculture
WP	Wettable Powder

ABSTRACT

Name : Dipak Timalsina, Manoj Sapkota, Mukesh Kumar Yadav and Sapana Ghimire

Semester : 8th Degree: B.Sc. in Agriculture

Major Advisor: Prof. Madhav Pandey, Ph.D. Department: Genetics and Plant Breeding

An experiment was conducted in agronomy farm of Institute of Agriculture and Animal Science from July 31, 2015 to October 18, 2015 to characterize foxtail millet accession collected from different parts of Nepal. Twelve accessions were experimented in Randomized Complete Block Design with three replications. Of these, two accessions failed to emerge. Observations were taken for quantitative traits i.e. days to heading, days to anthesis, days to maturity, peduncle length, plant height, flag leaf length, flag leaf breadth, flag leaf length breadth ratio and stay green period and yield attributing traits i.e. panicle length, panicle exertion, number of panicle per square meter, hundred grain weight, five panicle weight and yield per plant. The mean performance was obtained and correlation analysis was performed between grain yield and other traits. Observations were also taken for qualitative traits i.e. tip of first leaf, anthocyanin at leaf base, lobe compactness, length of bristles, anthocyanin presence, leaf blade altitude, flag leaf color, lobe in panicles, panicle lodging, inflorescence compactness, overall color, panicle anthocyanin, panicle shape and growth habit. Biodiversity index and evenness of these traits were also calculated for assessing the genetic diversity. Significant differences were observed among the accessions for many characters Based on quantitative and yield attributing traits, Humla-149 was considered the best performing accession. The UPGMA clustering and PCA analysis revealed three distinct clusters of the studied accessions. Most closely related accessions were Co-1896 and Co-5645 and most distantly related accessions were Co-1896 and Humla-522.The accessions were found most diverse for the panicle

lodging trait and least diverse in terms of growth habit. The ten accessions were highly even of the trait tip leaf type and least even for growth habit.

Prof. Madhav Pandey, Ph.D.

Major Advisor

Dipak Timalsina, Manoj Sapkota,

Mukesh Kumar Yadav and Sapana Ghimire

Authors

शोध-सार

नाम : दिपक तिमल्सिना, मनोज सापकोटा, मुकेश कुमार यादव र सपना घिमिरे

सत्रान्त: आठौं उपाधि: कृषि स्नातक

मुख्य सल्लाहकार : प्रा. माधव पाण्डे, पि.एच.डी.

बिभाग: बाली प्रजनन्

कगुनोका १२ एसेस्सनको चिनारी गर्ने र विभिन्न गुणहरुको वर्णन तथा अध्धयन गर्ने उदेश्यले जुलाई ३१, २०१५ देखि अक्टोबर १८, २०१५ मा कृषि तथा पशु बिज्ञान अध्धयन संस्था , रामपुर, चितवनको बाली बिज्ञान फार्ममा आर्.सी.बी.डी. डिजाइन प्रयोग गरेर अनुसन्धान कार्य सम्पन्न गरियो | रोपिएका १२ एसेस्सनमध्य २ एसेस्सन अंकुरण नभएको कारणले बाकी १० एसेस्सनको अध्धयन गरियो | अध्धयन गरिएका १० एसेस्सनहरुको गुबो पसाउन लाग्ने दिन, बाला पसाउन लाग्ने दिन, परिपक्क हुन लाग्ने दिन, पेडंकलको लम्बाई, बिरुवाको उचाई, झण्डे पातको लम्बाई, चौडाई र त्येसको अनुपात, र उपज निर्धारण गुण जस्तै बालाको लम्बाई, प्रति घन क्षेत्रफलको बाला संख्या, सय दाना तौल, पांच बालाको तौल र प्रति बिरुवा उपज जस्ता परिणात्मक गुणहरु सबैको आकंडा राखियो | यी उपज गुण र गुणहरुको गुण औसत र अन्य गुणहरुसंग कोरीलेसन निकालियो| पहिलो पातको टुप्पोको प्रकार, पातको आधारमा एन्थोसायनिन भएको नभएको, बालाको प्रकार, झण्डे पातको रंग, बालाको आकार, बालाको झुकाई र बिरुवाको उमार बानी जस्ता गुणीय गुणहरुको पनि आकडा राखियो | यी गुणहरुको जैविक विविधता सूचांक र समानता निकालेर जातीय विविधताको अध्धयन गरियो | अध्धयन

प्रा. माधव पाण्डे, पि.एच.डी.

दिपक तिमल्सिना, मनोज सापकोटा, मुकेश कुमार यादव र सपना घिमिरे

गरिएका एसेस्सनहरु माझ विभिन्न गुणहरुमा औचित्यपूर्ण फरक पाइयो| परिणात्मक र उपज निर्धारक गुणहरुका आधारमा हुम्ला-१४९ लाई उत्कृष्ट एसेस्सन भएको पाइयो | यू.पी.जी.एम.ए. क्लस्टरिंग र पी.सी.ए. ले अध्धयन गरिएका एसेस्सनहरुलाई तीनवटा क्लस्टरमा बिभाजन गरेको पाइयो | सीओ-१८९६ र सीओ-५६४५ सबैभन्दा निकट सम्बन्धित भएको पाइयो भने सीओ-१८९६ र हुम्ला-५२२ सबैभन्दा कम सम्बन्धित एसेस्सनहरुको रहेको पाइयो| एसेस्सनहरु बाला झुकाईमा सबैभन्दा धेरै बिबिध भेटियो भने, उमार बानीमा सबै भन्दा कम बिबिध भएको पाइयो | अध्धयन गरिएका १० एसेस्सनहरु पहिलो पातको टुप्पोको प्रकारमा धेरै समान भेटिए भने उमार बानीको गुण सबैभन्दा धेरै असमान भएको पाइयो |

1 INTRODUCTION

1.1 Background

Millets are small-seeded grasses that are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture (Singh et al., 2015), making them the preferred cereal crop for drought prone areas. Millets were domesticated in highlands of central China, possibly about 8000 years ago (Amgai et al., 2011). Foxtail millet (*Setaria italica* (L.) Beauv.) is thought to be native to southern Asia and is considered one of the oldest cultivated millets (Oelke, 1990). It is an important cereal crop in Nepal, cultivated on 271,183 ha with the production of 304,105 mt and productivity of 1,121 kg/ha (Statistical Information on Nepalese Agriculture: http://www.moad.gov.np/ uploads/files/ Year%20 book%202014.pdf).

Foxtail millet belongs to family Poaceae and subfamily Panicoideae. It is a self-pollinating crop with chromosome numbers, 2n=18 (Fedorov, 1974). It is cultivated in 26 countries, and ranks second among the millets in terms of global production. About six million tons of foxtail millet is produced globally; mainly in southern Europe and in temperate, subtropical, and tropical Asia (Marathee, 1993). Foxtail millet has been an important cereal since ancient times and has contributed greatly to human civilization in Asia and Europe (Li et al., 1996; Lu et al., 2009). Apart from being rich in a variety of amino acids and nutritional minerals taken as food, foxtail millet exhibits high photosynthetic efficiency and drought tolerance (Dai et al., 2008; Dai et al., 2011a). Furthermore, foxtail millet porridge is a traditional food in Asia, Europe, North America, Australia, and North Africa. Foxtail millet is generally grown on marginal lands and with little or no irrigation water and can survive with little fertilizer and without organic manures (Dai et al., 2009; Dai et al., 2011a, b).

1.2 Botanical Description

Setaria italica (Foxtail Millet) Classification (USDA, 2006)

Kingdom	Plantae - Plants
Subkingdom	Tracheobionta - Vascular plants
Super division	Spermatophyta - Seed plants
Division	Magnoliophyta - Flowering plants
Class	Liliopsida - Monocotyledons
Subclass	Commelinidae
Order	Cyperales
Family	Poaceae - Grass family
Genus	*Setaria* Beauv. - bristlegrass
Species	*italica* (L.) Beauv
Common Name:	Bristle grass; Foxtail; Italian, German, or Hay Millet

The foxtail millet is an annual plant with stems that branch little, and with a well-developed, deep root system. The tubular stalk is filled with loose tissues. The leaf-blade is wide-lanceolate, long-acuminate, dense scabrous, and may have a brightly coloured midrib; leaf edges serrate. Leaf-sheaths longer than the nodes; collar indistinct, ligule small, short, and thick. Inflorescence has main stalk with shortened branching bearing spikes and bristles. Flowers two per spikelet, the upper one bisexual. In cultivated varieties there are two to three bristles per spikelet. Fruit a caryopsis; grain of various colours; seeds enclosed in thin, papery hulls, largely removed by threshing, leaving free the small, convex seed, which is oval or elliptical (Malm and Rachie, 1971).

1.3 Nutritive value and Uses

The grain of the foxtail millet can be cooked in the same manner as rice and has many food applications, for example, porridge, pudding, breads, cakes, flour, chips, rolls, noodles etc. Healthy and therapeutic food products can be prepared from foxtail millet and used to maintain good health (Kamatar, 2013; Kamatar et al., 2014a; Kamatar et al., 2014 b; Kotagi et al., 2013).

A high intake of foxtail millet based dietary fiber, improves glycemic control, decreases hyperinsulinemia and lowers plasma lipid concentrations in patients with type-2 diabetes (Jali et al., 2012). According to Tirajoh (2012), foxtail millet can be used as a poultry feed ingredient to replace corn, specifically yellow foxtail millet. In western countries, millets are grown primarily as birdseed, hay or as an emergency cash crop. In developing countries, millets are consumed by people from the low economic strata and as forage crop (Baker, 2003). They are nutritionally comparable or even superior to staple cereals such as rice and wheat (Gopalan et al., 2004). Millets are rich in vitamins, minerals, sulphur-containing amino acids and phytochemicals, and hence are termed as nutri-cereals. They have higher proportions of non-starchy polysaccharides and dietary fibre. Millets release sugars slowly and thus have a low glycemic index (Bala Ravi, 2004). Millets are being used for the production of malt in the brewing industry, millet flour serves as a stabilizer (in ice creams), it is added to wheat flour for some special types of breads and pastries. Some millet grain extracts like silicic acid and fatty acids are being used in cosmetic industry for the hair, skin and nail care products.

1.4 Justification of the research

Millets have been neglected despite their nutritive value and therapeutic uses (Anju and Sarita, 2010). Being rich in protein and calcium, millet serves as an important staple food for rural populations in tropical and sub-tropical developing countries, where calcium

deficiency and anemia are wide spread. Even though, the crop had such significant importance, work done on the study and development of this crop is negligible.

Not much study and research has been done on the neglected crops, especially on foxtail millets. Characterization of the accessions of foxtail millet can provide pivotal information for crop breeding and management of genetic resources. Characterization and evaluation of indigenous foxtail millet landraces is necessary for the utilization in crop improvement. Also, clustering these accessions can be useful to identify accessions with diverse traits, which can be useful in breeding programs. In Nepal, most of the crop breeding research activities are focused on major crops like rice, maize, and wheat and the efforts towards the improvement of minor crop like foxtail millet are inadequate. There has only been some limited research and handful of publication on the study of this underutilized crop in the country. Thus, this research can act as a pivotal study as an initiation as well as a reference for further researches on millets in Nepal.

Compared to the developed world where millet landraces were nearly extinct and almost forgotten in recent times; the major crop are getting more focus and the millets are being neglected, the crop has the potential to serve well as an alternative source of nutrition to fight the food insecurity. The farmers can grow this crop in the marginal and fallow lands. Foxtail millet being a short duration crop can increase the cropping intensity and cropping index. The characterization of foxtail millets will help to explore the genetic variability available in Nepal, which ultimately contribute in exploitation of genetic resources for the future breeding research.

This research will also explore the adaptability of foxtail millet in lower altitudes like Chitwan valley. Accessions performing well in such condition can further be taken into breeding activities and promoting the cultivation of the crop.

1.5 Objectives

The objectives of the research were:

a) To characterize agro-morphology and evaluate grain yield of foxtail millet accession collected from different parts of Nepal

b) To analyze genetic diversity and association among economically important traits.

2 LITERATURE REVIEW

Nepal is rich in millet genotypes, which are grown up to 3150 m (Upreti, 1999). About 790 millet accessions have been collected from various parts of Nepal (Gupta et al., 2000). Genetic diversity and genetic relatedness study is necessary for crop improvement developing appropriate strategies for the conservation, exploitation and utilization of millet accession (Baniya, 1999; Joshi and Joshi, 2002; Upadhya and Joshi, 2003). A high level of genetic diversity was reported among the Nepalese foxtail millet accessions by Nakayama et al. (1999).

A large number of local foxtail millet landraces have been collected and characterized by Reddy et al. (2006; global collection, n=1535), Hirano et al. (2011) in Japan and Amgai et al. (2011) in Nepal. In the study by Reddy et. al. (2006) 21 Nepalese foxtail millet accessions were included.

Amgai et. al., (2011) studied five accessions of Nepalese foxtail millet collected from Dolpa, Mugu, Bajura, Bajhang and Lamjung districts of Nepal. A wide range of variability was found for different agromorphological and yield attributing traits.

Nepalese foxtail millet landraces were grouped into tropical group based on the *Pro2f* allele of prolamin (Nakayama et al., 1999), however, the study revealed Pro*2b* allele was uncommon in them. Variation in esterase alleles in Nepalese foxtail millets were reported by Kawase and Sakamoto (1984). Considerable variability is available in foxtail millet for yield and yield contributing traits (Kamatar et al., 2014; Brunda et al., 2014) and for nutritional parameters (Brunda et al., 2014; Kamatar et al., 2015).

3 METHODOLOGY

3.1 Site of the research

The research was conducted at Agronomy field of Institute of Agriculture and Animal Science, Rampur (27.642453 ° latitude and 84.345760° longitude; 190 masl). The soil type of the research field was a sandy loam. The climate of Rampur is humid sub-tropical with average annual rainfall of 2000 mm, which occurs predominantly during June-September.

3.2 Cropping history

The cropping history of the experiment field was Buckwheat-Fallow.

3.3 Soil Analysis

Composite soil sample was taken from the experiment field during land preparation at a depth of 30 cm. The soil was dried, grounded, sieved through 2 mm sieve and chemical and physical properties were analysed at Soil Science Directorate, Nepal Agriculture Research Council, Khumaltar, Lalitpur, Nepal. The details of the soil analysis is given in Table 1.

Table 1: Physical and chemical properties of the soil at experimental site, IAAS, Rampur (2015), analysed at Soil Science Division, NARC, Khumaltar, Lalitpur, Nepal

Property	Content	Method
pH	5.8	1:1 soil water ratio
Organic matter	1.9 %	Walkey and Black method
Total Nitrogen	0.08 %	Micro-Kjeldahl method
P_2O_5	22 ppm	Modified Olsens Bicarbonate method
K_2O	85 ppm	Flame Photometer method

3.4 Agrometeorological features

The research location is characteristics of subtropical climate. The climatic data of the research period (July-October 2015) presented in Figure 1.

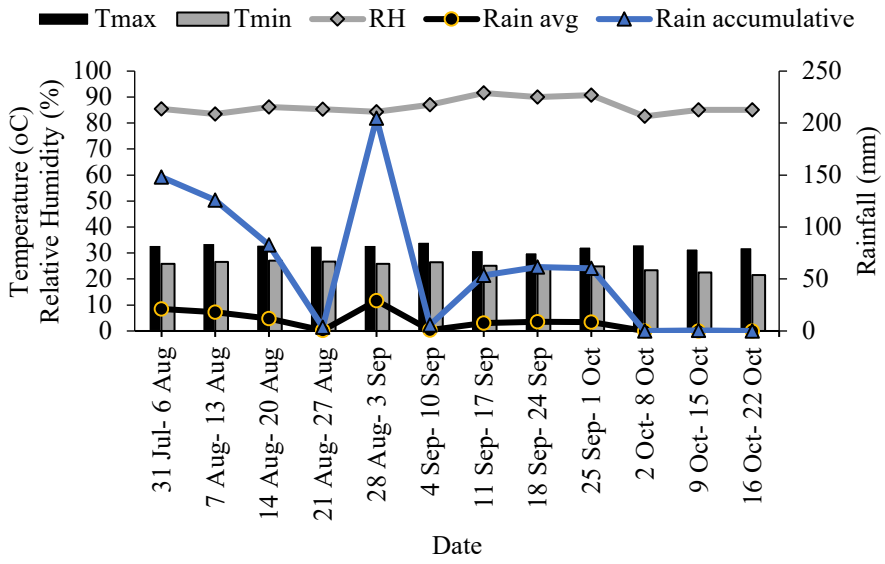


Figure 1: Agro-meteorological data during the research period

(Source: NMRP, Rampur, Chitwan)

3.5 Plant materials

A total of 12 foxtail millet (*Setaria italica* (L.) Beauv.) Accessions collected from different parts of Nepal were studied (Table 2; Figure 2). The seed samples were obtained from National Genetic Resource Centre, Khumaltar, Lalitpur, Nepal.

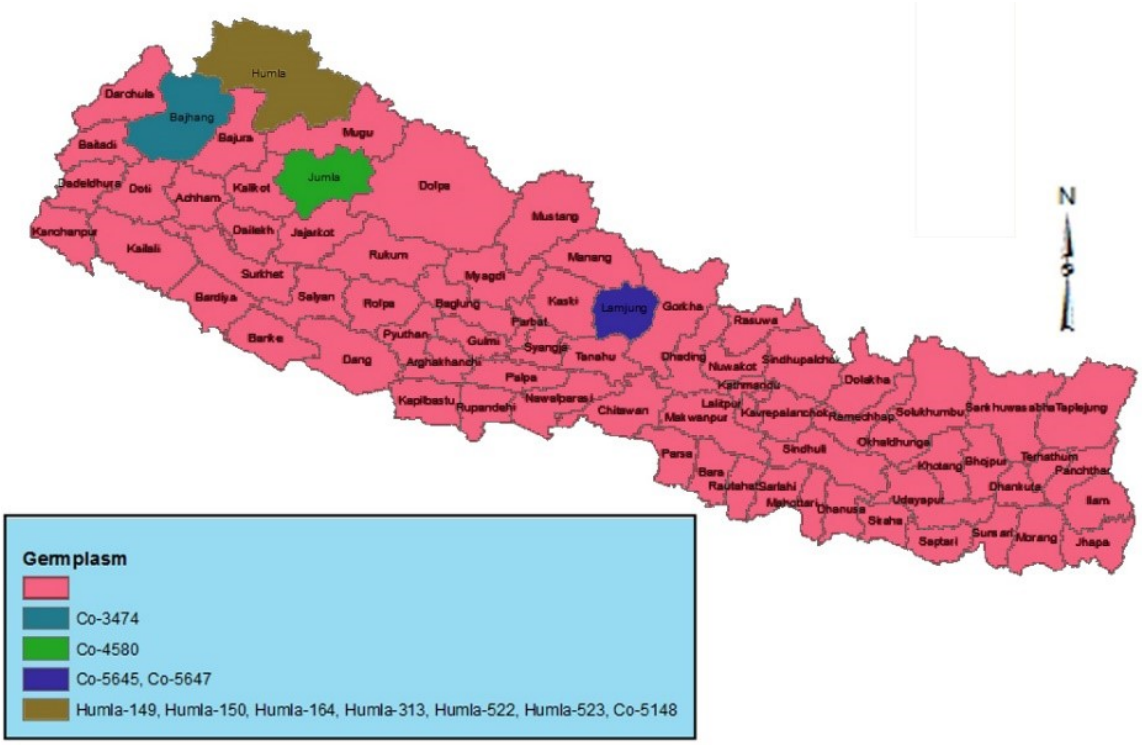


Figure 2: Map of Nepal showing collection sites of studied foxtail millet accessions

Table 2: Details of 12 foxtail millet accessions included in the study

SN	Accession	Local name	District	Location	Altitude (m, asl)
1	Co-1896	Kaguno	Jumla	Chandannath-1	2,290
2	Co-3474	Kaguno	Bajhang	Sunkuda-8, Suwakot	1,764
3	Co-4580	Kaguno	Jumla	Guthichaur-5, Manisanghu	2,779
4	Co-5148	KaloKaguno	Humla	Kharpunath-7	2,200
5	Co-5645	SetoKaguno	Lamjung	Ghanpokhara-6	1,800
6	Co-5647	Kauno	Lamjung	Taghring-1	1,700
7	Humla-149	RatoKaguno	Humla	Raya	2,300
8	Humla-150	KaloKaguno	Humla	Raya	2,300
9	Humla-164	PiyaloKaguno	Humla	Chhipra	2,100
10	Humla-213	KaloKaguno	Humla	Saya	2,200
11	Humla-522	SetoKaguno	Humla	Syanda	2,050
12	Humla-523	RatoKaguno	Humla	Syanda	2,050

3.6 Experimental Design and Field Layout

The research plot was laid out in Randomized Complete Block Design (RCBD) with 12 foxtail millet accessions as treatment and three replications. The unit plot size was 1 m^2 and had 4 rows of crop sown at a distance of 25 cm between the rows. Inter block spacing of 1m and inter plot spacing of 50 cm was maintained. The layout of the field is presented in the Figure 3.

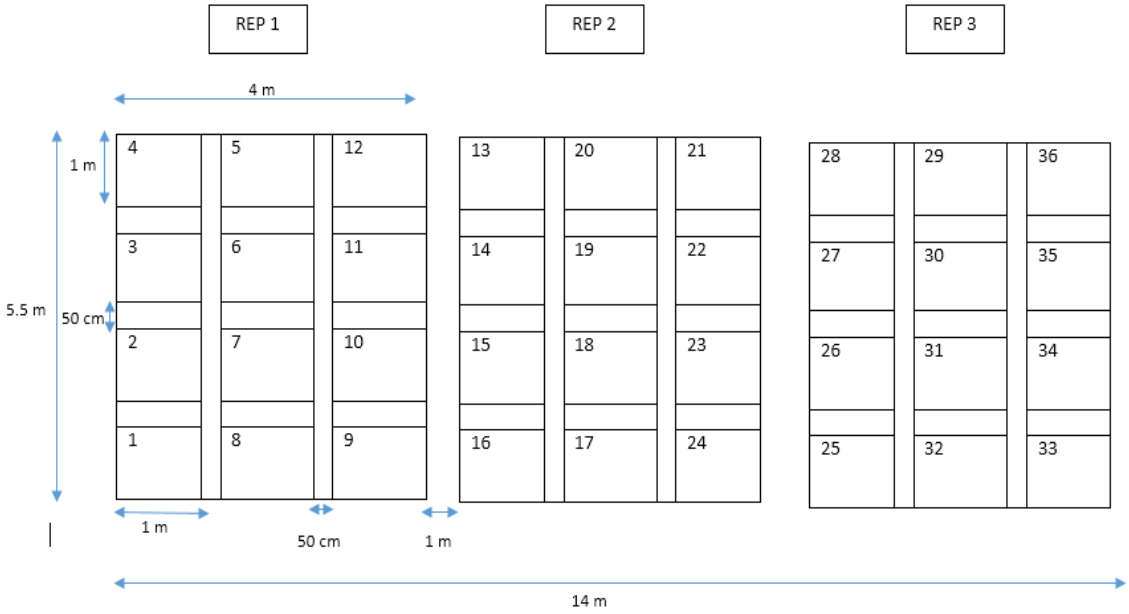


Figure 3: Layout of the research plot

3.7 Land preparation

The land was prepared 2 days prior to sowing (July 29, 2015) with one harrowing followed by disc ploughing and the leveling off the ground.

3.8 Fertilization

Fertilizer was applied at the rate of 30:20:0 kg NPK per ha with DAP 4.347 gm and Urea 4.82 gm per plot. Complete dose of Urea was applied during field preparation.

3.9 Sowing

The seeds were sown continuous at about 2.5 cm deep on rows with inter row spacing of 25 cm. Sowing was done on July 31st 2015. The seed rate row^{-1} was approximately 0.416 mg.

Mulching was done on the same day of sowing to protect the seeds from rain drop splashes as well as from the birds. Stubbles of *Imperata cylindrica (*Siru) were used for mulching. The mulching was removed after seedling emergence.

3.10 Intercultural operations

3.10.1 Weeding

Hand weeding was done twice on August 10 and September 10 to maintain a weed free crop stand. The major weed observed in the field was *Cynodon dactylon.*

3.10.2 Thinning out

Thinning out as well as gap filling was done to maintain the plant population. The gap filling was done with the thinned out plants within the plots where the emergence was erratic.

Two sprays of UPL-SAAF fungicide (Carbendazim 12% + Mancozeb 63% WP) was done at the rate of 1.5 gm/ l of water at 7 days interval to control the *Helmintho sporium b*light infestation.

Two sprays of Jayashree Rasayan Udhyog-Spine 505(Chloropyriphos 50% + Cypermethrin 5% EC) were done for the control of stem borer and Leaf roller at an interval of 15 days at head emergence stage.

3.11 Harvesting

The panicles in each plot were harvested separately by cutting from the peduncle base and placed in paper envelops. The harvestings were done from 23rd September 2015 till 18th October 2015.

3.12 Data collection and recording

The different qualitative and quantitative data recorded were as follow.

3.12.1 Phenological observations

3.12.1.1 Days to heading

Days to heading were noted down when emergence of panicle was observed visually in the 90% of the plants in the plot.

3.12.1.2 Flag leaf duration

Flag leaf duration was measured as:

Flag leaf duration = Date of complete senescence of flag leaf – days of complete emergence of flag leaf

3.12.1.3 Days to anthesis

Days to anthesis were recorded when 90% plant of the plot showed anthesis.

3.12.1.4 Days to flag leaf senescence

Flag leaf senescence was noted when 50% flag leaf senescence was observed in 90% of the plants in the plot.

3.12.1.5 Days to Maturity

It was noted as the date in which glumes loose chlorophyll and turned yellow in all the panicles.

3.12.1.6 Flag leaf length breadth ratio

Length of flag leaf was measured from the tip to the base of flag leaf of 3 randomly selected plants. Similarly, breadth was also recorded from the widest region of the leaf of three randomly selected plants. The length breadth ratio of the leaf was calculated by the formula:

$$\text{Flag leaf length breadth ratio} = \frac{\text{avegare length of the flag lef}}{\text{average breadth of the flag leaf}}$$

3.12.1.7 Plant height

The plant height was measured in centimeters from soil surface up to the tip of the panicle at the time of harvest.

3.12.1.8 Panicle length

Panicle length was measured from the base to tip of the panicle.

3.12.1.9 Hundred seed weight

Hundred seeds from each plot was randomly taken and weight determined using an electronic balance.

3.12.1.10 Yield per plant

Yield per plant was measured by dividing the total yield of the plot by the total plant number in the plot.

3.12.2 Qualitative Observations

Characters were evaluated following the foxtail millet descriptor (IBPGR, 1985).

- First leaf shape: assessed at Zadok's scale 11 : (1) pointed (2) pointed to rounded (3) rounded
- Seedling anthocyanin coloration of basal leaf sheath: assessed at Zadok's 15 (1) present (0) absent
- Foliage colour: assessed at Zadok's 35: (1) light green, (3) green (5) dark green
- Plant growth habit: assessed at Zadok's 35: (1) erect (2) semi erect (3) prostate
- Plant anthocyanin coloration of leaf pedestal assessed at Zadok's 35: (1) present (0) absent
- Leaf altitude of blade: assessed at Zadok's47: (1) erect, (2) semi erect, (3) horizontal and (4) drooping
- Panicle anthocyanin coloration of bristles: assessed at Zadok's65 : (1) presence and (0) absent

- Anther color: assessed at Zadok's 65: (1) white (2) orange and (3) brown
- Length of bristles: assessed at Zadok's 65: (1) short, (3) medium and (5) long
- Panicle attitude in relation to stem: assessed at Zadok's 91: (1) erect (2) semi erect (3) horizontal (4) moderately drooping (5) strongly drooping
- Panicle shape: assessed at Zadok's 91: (1) conical, (2) spindle, (3) cylindrical, (4) club, (5) duck mouth, (6) cat foot and (7) branched.

3.13 Statistical analysis

Data entry and processing was carried out using Microsoft Excel 2016 and Microsoft Word 2016 software. Mean and Standard deviations, Analysis of variance (ANOVA), mean performance and DMRT was calculated by using RStudio version 3.1.1. Pearson's correlation co-efficient was computed by using IBM SPSS Statistics 21 and diversity indices were calculated by using Microsoft Excel 2016. Multivariate analysis was done with Minitab 15.0.

3.13.1 Mean performance

On the basis of individual plant observations, the mean performance for each character was computed as follow:

$$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} xi$$

Where, $\bar{x}$ = mean performance, xi = individual value, n = number of observations

3.13.2 Analysis of Variance (ANOVA)

The analysis of variance for different characters was performed on mean data separately in order to partition the variability due to different sources. The method given by Andreas et. al. (2007) was followed. The structure of ANOVA is presented in Table 3.

Table 3: Analysis of variance for RCBD

Source of variation	degree of freedom	Sum of squares	Mean sum of squares	F-value	Pr (>F)
Replication (r)	r-1	SSr	MSr	$\frac{MSr}{MSe}$	
Accession (g)	g-1	SSg	MSg	$\frac{MSg}{MSe}$	
Error		SSe	MSe		
Total	n-1	SSt	MSt		

3.13.3 Shannon Weiner index

The Shannon index was calculated as follows:

$$\text{Shannon–Weiner index}(H') = -\sum_{i=1}^{R} p_i \, ln \, p_i$$

Where p_i is the proportion of the trait. i.e. $\mathrm{p_i} = \frac{\text{population bearing given trait}}{\text{total population}}$

3.13.4 Evenness

Species evenness refers to how close in numbers each species in an environment is. Mathematically it is defined as a diversity index, a measure of biodiversity which quantifies how equal the community is numerically.

Evenness $(E) = \frac{H}{ln(S)}$, where S= total number of variation cases.

3.13.5 Multivariate Analysis

3.13.5.1 Cluster analysis

Cluster analysis is a type of multivariate technique whose primary purpose is to group individuals or objects based on the characteristics they possess so that individuals with similar description are mathematically gathered into the same cluster. The resulting cluster of individuals should exhibit higher within-cluster homogeneity and between

cluster heterogeneity. (Hair et al., 1955). Hierarchical clustering methods are commonly employed in analysis of genetic diversity in accessions. This method proceeds either by a series of successive mergers or by a series of successive divisions of a group of individuals. Former known as 'agglomerative hierarchical' methods, start with a single individual. Thus initially there as many clusters as individuals (Mohammadi and Prasanna, 2003). The most similar individuals are first grouped and these initial groups are merged according to their similarities. Among various agglomerative hierarchical methods, the UPGMA (Unweighted Paired Group Method using Arithmetic Averages) (Panchen, 1992) is the most commonly adopted clustering algorithm, followed by the Ward's minimum variance method (Ward, 1963).

3.13.5.2 Principal Component Analysis (PCA)

PCA can be utilized to derive a 2 or 3 dimensional scatter plot of individuals such that the geometrical distances among the individuals in the plot reflects the genetic distances among them with minimal distortion among individuals in the pot reflects the genetic distances among them with minimal distortion. Aggregation of individual in such a plot will reveal set of genetically similar individuals (Karp et. al., 1997). The first step in PCA is to calculate Eigen Values, which define the amount of total variation that is displayed in the P axes. The first PC summarizes most of the variability present in the original data relative to all remaining PCs. The second PC explains most of the variability not summarized by the first PC and uncorrelated with the first and so on (Jolliffe, 1986). PCA can be performed on two types of data matrices: variance-covariance matrix and correlation matrix. In the use of these two types of matrices, one has to consider that with the variance covariance matrix, absolute changes among individuals can be studied. But, with correlation matrix, only one difference relative to the standardized data can be interpreted (Wiley, 1981).

4 RESULTS

Among the twelve accessions used in the study, two accessions (Co-4580 and Co-5647) did not emerge. The results on the observation of the remaining ten accessions are described. The analysis of variance, mean performance, diversity indices, correlation coefficients of quantitative traits and the description on qualitative traits are presented below.

4.1 Quantitative traits

Significant variation was found among the studied accessions for days to heading, days to anthesis, days to maturity, yield per plant, panicle exertion, panicle length, peduncle length, flag leaf length-breadth ratio, stay green period and number of panicle per m^2. It was non-significant for plant height, flag leaf length, flag leaf breadth, five panicle weight and hundred grains weight (Appendix 1). Mean performance of accessions for these traits is presented in Appendix 2.

4.1.1 Days to heading

The mean number of days to heading was 44.633 days. The minimum days to heading was 34.666 days which was exhibited by Humla-149, whereas the maximum number of days to heading was 55 days, exhibited by Co-3474.

4.1.2 Days to anthesis

The mean days to anthesis was observed to be 49.933 days. The minimum days to anthesis was shown by Co-5148 and maximum number of days to anthesis by Co-3474 (57.666 days).

4.1.3 Days to maturity

The mean number of days to heading was 67.4 days. The minimum days to maturity was 58.00 days which was exhibited by Humla-150 whereas maximum days to maturity was 76.66 days which was exhibited by Co-3474.

4.1.4 Yield per plant

The mean yield per plant was 0.094 gm. The maximum yield per plant was 0.155 gm which was yielded by Co-5645. The minimum yield per plant was 0.0373 gm which was exhibited by Humla-522.

4.1.5 Panicle exertion

The mean panicle exertion was 10.03 cm. The maximum panicle exertion was 16.11 cm which was exhibited by Co-5148. The minimum panicle exertion was 5.277 cm which was exhibited by Co-3474 and Humla-522.

4.1.6 Panicle length

The mean panicle length was 8.857 cm. The maximum panicle length was exhibited by Humla-149 which had panicle length of 11.978 cm. The minimum panicle was 5.777 cm which was exhibited by Humla-213.

4.1.7 Peduncle length

The mean peduncle length was 19.511 cm. The maximum peduncle length was exhibited by Co-5148 which had panicle length of 27.766 cm. The minimum panicle was 8.888 cm which was exhibited by Humla-522.

4.2.8 Flag leaf length-breadth ratio

The mean flag leaf length-breadth ratio was 13.522. The maximum flag leaf length-breadth ratio was exhibited by Co-5645 which had flag leaf length-breadth ratio of 15.893. The minimum flag leaf length-breadth ratio was 9.741 which was exhibited by Humla-522.

4.1.9 Stay green period

The mean number of days of stay green was 19.333 days. The minimum days of stay green period was 12.666 days which was exhibited by Humla-150 whereas the maximum number of days to heading was 26.00 days, exhibited by Co-1896.

4.1.10 Number of panicle per square meter

The mean number of panicle per m^2 was 45.8. The minimum number of panicle per m^2 was 25.66 which was exhibited by Humla-522 whereas the maximum number of panicle per m^2 was 71.666, exhibited by Humla-149.

4.1.11 Correlation coefficient analysis

Pearson's correlation coefficients between different studied traits are presented in Appendix 3.

Days to heading had highly significant positive relationship with days to anthesis and days to maturity whereas days to heading had highly significant negative correlation with panicle exertion, peduncle length, flag leaf length, flag leaf length breadth ratio, number of panicle per square meter and yield per plant. Significant negative correlation was observed between days to heading and hundred grain weight. Days to heading had negative and non-significant correlation with panicle length, plant height, flag leaf breadth, stay green period and five panicle weight (Appendix 3).

Days to anthesis had highly significant positive correlation with days to maturity whereas days to anthesis had highly significant negative correlation with panicle exertion, peduncle length, flag leaf length, flag leaf length breadth ratio, number of panicle per square meter and yield per plant. Non-significant negative correlation was found between days to anthesis with panicle length, plant height, flag leaf breadth, stay green period, five panicle weight and hundred grain weight.

Days to maturity had non-significant positive correlation with plant height and stay green period. Days to maturity had highly significant negative correlation with panicle exertion, peduncle length and flag leaf length breadth ratio. Significant negative correlation was observed between days to maturity and flag leaf length. Days to maturity had non-

significant negative correlation with panicle length, flag leaf breadth, five panicle weight, number of panicle per square meter, hundred grain weight and yield per plant.

Panicle length had highly significant positive correlation with plant height, flag leaf length, flag leaf breadth, five panicle weight and number of panicle per square meter whereas panicle length had non-significant positive correlation with panicle exertion, peduncle length, flag leaf length breadth ratio, stay green period, hundred grain weight and yield per plant.

Panicle exertion had highly significant positive correlation with peduncle length, plant height flag leaf length, flag leaf length breadth ratio, five panicle weight and yield per plant. Panicle exertion had significant positive correlation with number of panicle per square meter. Non-significant positive correlation was observed between panicle exertion and flag leaf breadth, stay green and hundred grain weight.

Peduncle length had highly significant positive correlation with plant height, flag leaf length, flag leaf length breadth ratio, five panicle weight, number of panicle per square meter and yield per plant whereas non-significant positive correlation was observed between, flag leaf breadth, stay green period and hundred grain weight.

Plant height had highly significant positive correlation with flag leaf length, flag leaf breadth, five panicle weight, number of panicle per square meter and yield per plant whereas positive and significant correlation was observed between stay green period. Plant height had non-significant positive correlation with flag leaf length breadth ratio. Non-significant negative correlation was observed between plant height and hundred grain weight.

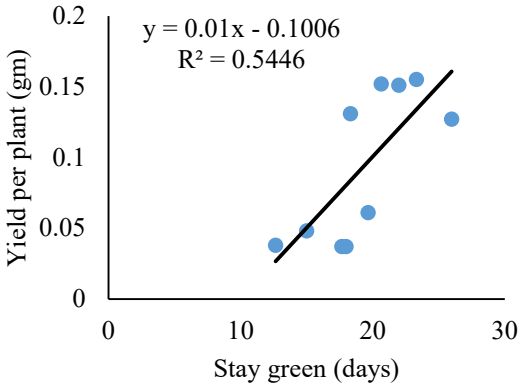
Flag leaf length had highly significant positive correlation with flag leaf breadth, flag leaf length breadth ratio, five panicle weight, number of panicle per square meter, yield per plant whereas flag leaf length had non-significant positive relation with stay

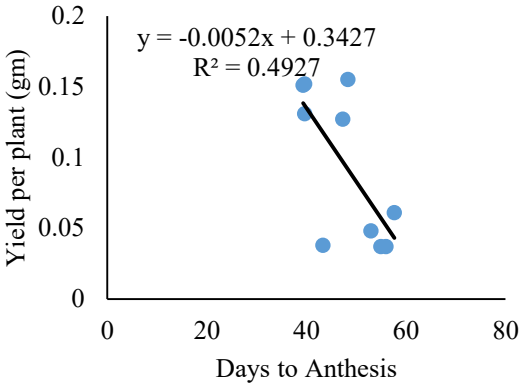
green period. Flag leaf length had non-significant negative correlation with hundred grain weight.

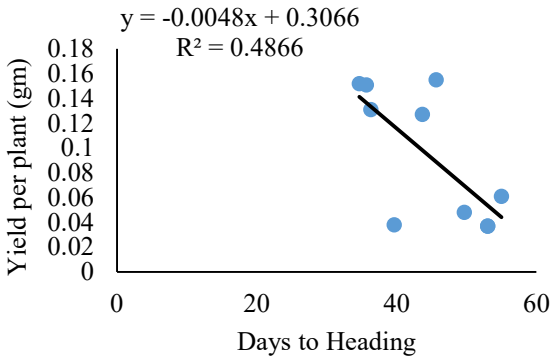
Flag leaf breadth had highly significant positive correlation with five panicle weight and number of panicle per square meter whereas flag leaf breadth had significant positive correlation with yield per plant. Flag leaf breadth had non-significant positive correlation with stay green period and hundred grain weight. Flag leaf breadth had non-significant negative correlation with flag leaf length breadth ration and hundred grain weight.

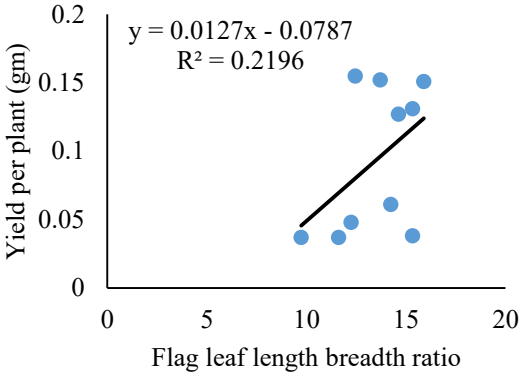
Flag leaf length breadth ratio had positive and non-significant correlation with stay green period, five panicle weight, no of panicle per square meter, 100 grain weight and yield per plant. Stay green period had positive and highly significant correlation with five panicle weight, number of panicle per square meter and yield per plant whereas stay green period had positive and non-significant correlation with hundred grain weight.

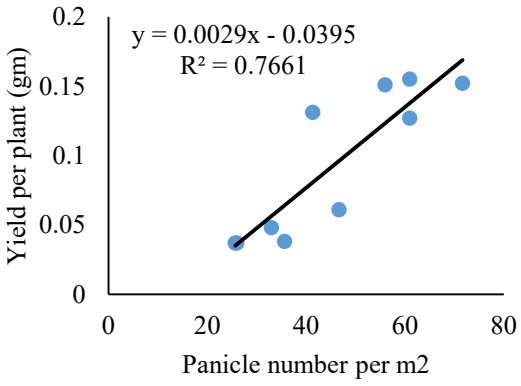
Five panicle weight had positive and highly significant correlation with number of panicle per square meter and yield per plant whereas five panicle weight had negative and non-significant correlation with hundred grain weight. Number of panicle per square meter had positive and highly significant correlation with yield per plant whereas positive and non-significant correlation with hundred grain weight. Negative and non-significant correlation was observed between hundred grain weight and yield per plant.

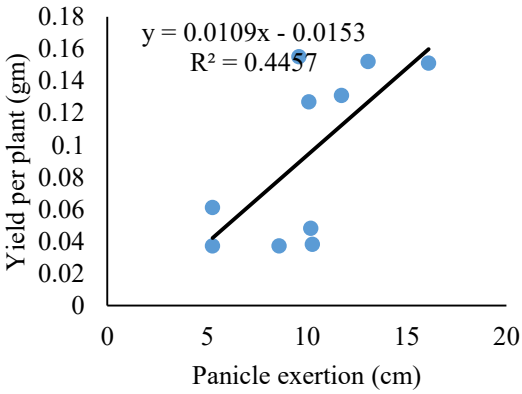

y = 0.01x - 0.1006
R² = 0.5446
Yield per plant (gm)
Stay green (days)
0.2
0.15
0.1
0.05
0
0
10
20
30


y = -0.0052x + 0.3427
R² = 0.4927
Yield per plant (gm)
Days to Anthesis
0.2
0.15
0.1
0.05
0
0
20
40
60
80


y = -0.0048x + 0.3066
R² = 0.4866
Yield per plant (gm)
Days to Heading
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
20
40
60


y = 0.0127x - 0.0787
R² = 0.2196
Yield per plant (gm)
Flag leaf length breadth ratio
0.2
0.15
0.1
0.05
0
0
5
10
15
20


y = 0.0029x - 0.0395
R² = 0.7661
Yield per plant (gm)
Panicle number per m2
0.2
0.15
0.1
0.05
0
0
20
40
60
80


y = 0.0109x - 0.0153
R² = 0.4457
Yield per plant (gm)
Panicle exertion (cm)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20

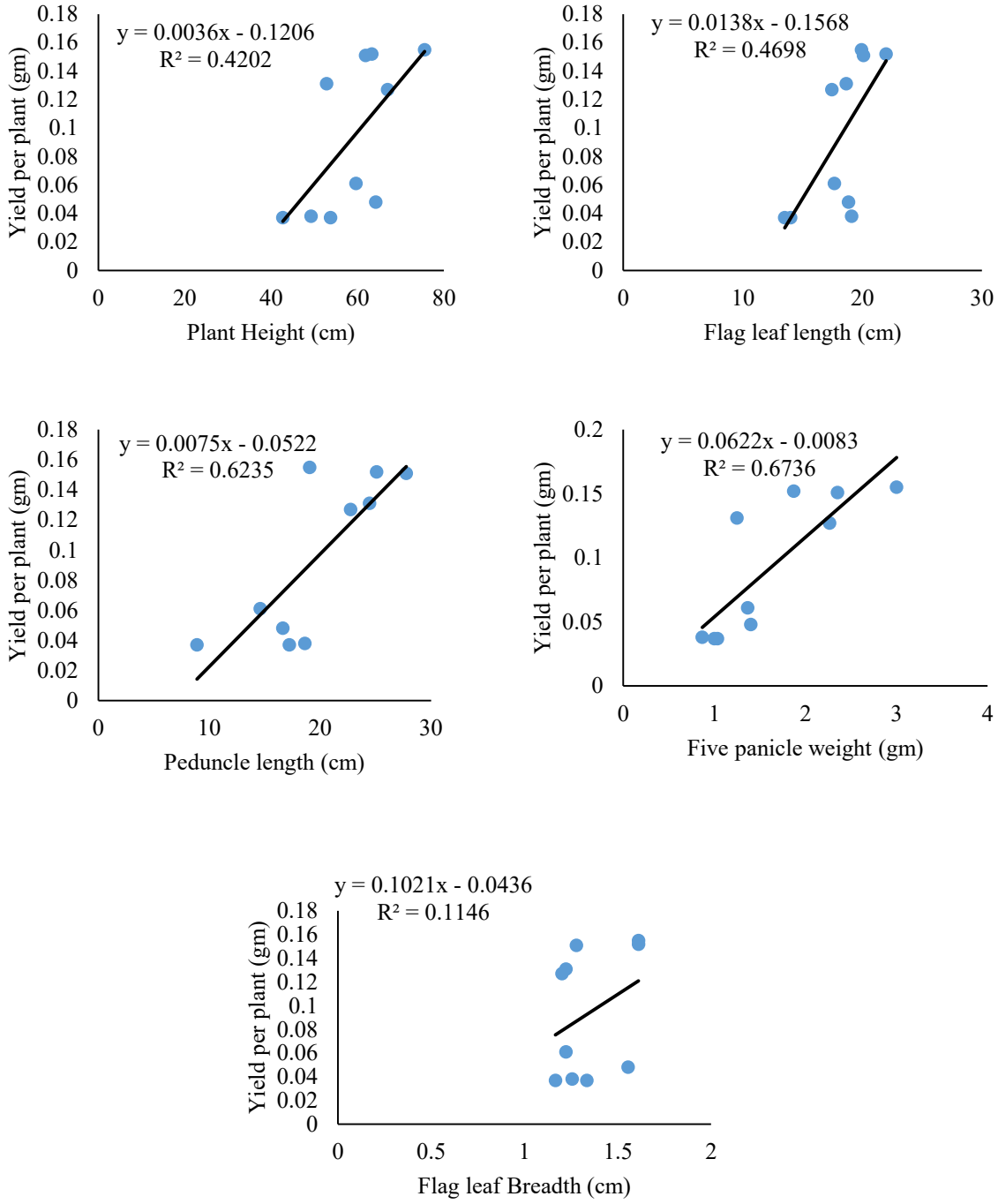


Figure 4: Scatter plots for yield per plant vs. other characters

4.2 Qualitative traits

Characterization of the qualitative traits revealed a wide variation among the accession. Variation was observed in terms of tip of cotyledon leaf, anthocyanin pigmentation, colour of the plant and leaf, growth habit of the plants, panicle shape, lobe

characteristics of the panicle and inflorescence. All the accessions were erect in habit and had white anther color. The qualitative attributes of the studied accessions presented in Appendix 5 & 6.

4.3 Genetic Diversity and Evenness

A fair amount of diversity was found in the collected accession. Shannon Wiener index showed highest diversity in traits of lobe compactness of panicle (1.3624) followed by panicle lodging (1.1595), inflorescence compactness (1.1235) and length of bristles (1.0681). Least diversity was observed in trait of growth habit (0.3926) followed by panicle anthocyanin coloration (0.4505) and lobes in panicles (0.5799).

Table 4: Shannon Weiner index and Evenness for different qualitative traits of foxtail millet

Traits	Shannon Wiener index	Evenness
Tip of first leaf	0.693147181	1
Anthocyanin Presence at Zadoks 15 stage	0.673011667	0.970950594
Overall color	0.867563228	0.789690082
Growth Habit	0.392674467	0.566509507
Anthocyanin at leaf base	0.684231765	0.987137774
Leaf blade altitude	1.014391994	0.923339384
length of bristles	1.068145261	0.972267716
Panicle anthocyanin	0.450561209	0.650022422
panicle lodging	1.159569797	0.836452798
panicle shape	0.63903186	0.581671866
lobe in panicles	0.579915171	0.836640742
lobe compactness	1.362447485	0.982798115
inflorescence compactness	1.123572876	0.810486508
Flag Leaf color	0.983104766	0.894860522

The evenness of the accession of different traits calculated revealed that tip type of first leaf (cotyledonary leaf) was very even (E=1) followed by anthocyanin pigmentation at leaf base (E=0.9871) and lobe compactness in panicle (E=0.9827). The growth habit (E=0.5665) followed by panicle shape (E=0.5816) and panicle anthocyanin pigmentation (E=0.6500) were the least even traits found in the accessions. The evenness of traits presented in Table 4.

4.4 Multivariate analysis

4.4.1 Cluster analysis

The clustering of foxtail millet accessions based on morpho-physiology, agronomic traits and grain yield presented in Figures5. Based on the similarity percentage and related characters three clusters were constructed. Most closely related accessions were Co-1896 and Co-5645 and most distantly related accessions were Co-1896 and Humla-522 (Figure 5).

In cluster 1, four accessions, Co-1896, Co-5645, Co-5148 and Humla-149 are grouped. It is observed that high value of traits like panicle exertion, panicle length, peduncle length, flag leaf length breadth ratio, panicle number per square meter and yield per plant are associated with the accessions found in this cluster.

In cluster 2, four accessions, Co-3474, Humla-164, Humla-213 and Humla-522 are grouped. It is observed that high value of trait like panicle length, days to heading, days to anthesis and days to maturity are associated with the accessions found in this cluster.

Likewise in cluster 3, two accessions, Humla-150 and Humla-523 are grouped. It is observed that high value of trait like harvest flag leaf length breadth ratio, and low value of traits like plant height, days to booting, days to heading and days to maturity are associated with the accessions found in this cluster.

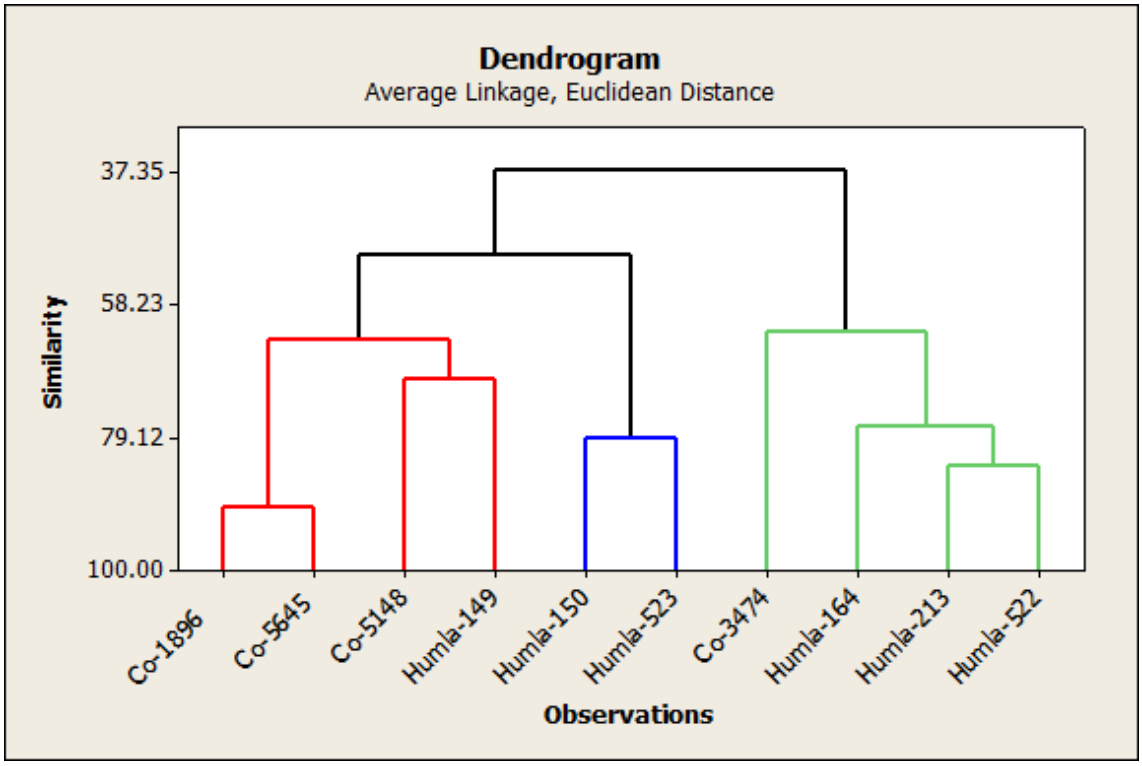


Figure 5: UPGMA clustering of 10 foxtail millet accessions grown at Rampur, Chitwan, Nepal in 2015

4.4.2 Principal Component Analysis (PCA)

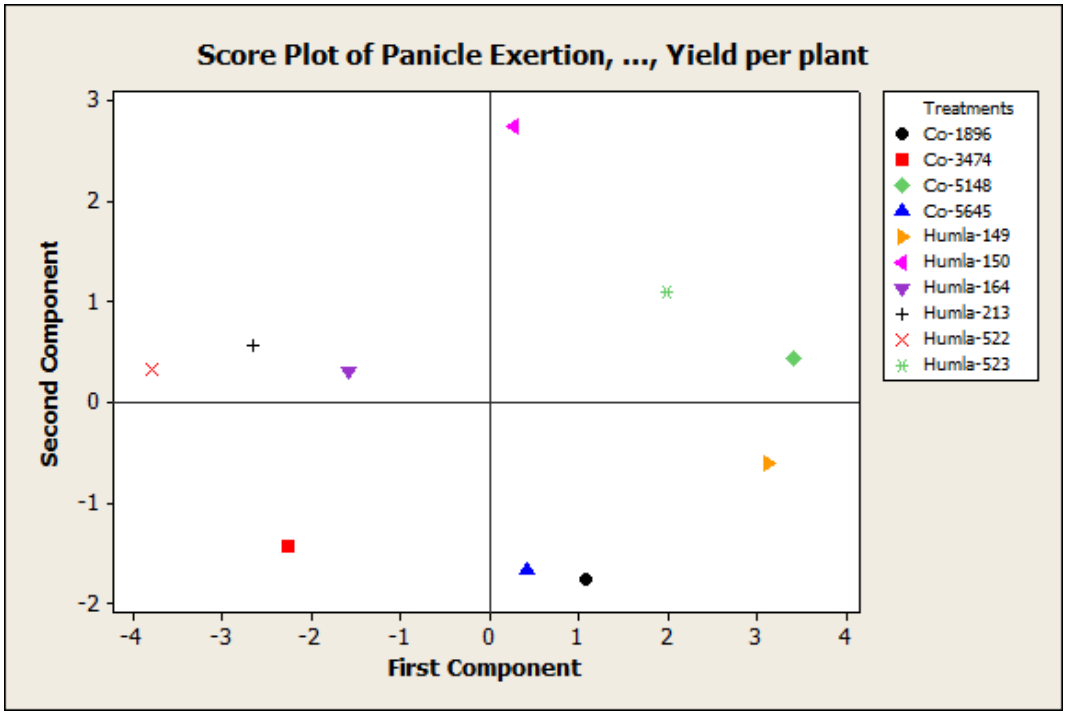


Figure 6: Principal component analysis of first two components of 10 foxtail millet accessions grown at Rampur, Chitwan, Nepal in 2015

The PCA in general confirmed the groupings obtained through cluster analysis. Results of PCA are given in Appendix 4 and Figure 6. The first two principal components with ≥ 1 eigen value accounted for 81.6 % of the total variance. Individually, PC 1, PC 2 and PC 3 contributed 61.9, 19.7 and 9.4 % of total variation, respectively.

4.5 Observation of disease pest in the experiment

The experiment was affected by some of the diseases and pests during the research period. These disease pests negatively affected the plant standing, plant growth, tillering habit, plant population and the final yield of the accessions. The disease pest observed in the research are as follows.

4.5.1 *Helminthosporium* Leaf Blight of foxtail millet

It is one of the major fungal diseases of foxtail millet caused by *Helminthosporium Drechs* (IBPGR, 1985). All the accessions were affected by this disease (Fig 7).

4.5.2 Stem borer of millet

Stem borer (*Sesmia* spp.) is one of the major insect of foxtail millet (IBPGR, 1985). This insect (Figure 8) resulted in the decrease in plant standing, plant growth, plant population and severely affected grain yield as well. The plant infected by this insect exhibited early and more tillering habit.

4.5.3 Leaf folder

Leaf folder is also a major pest of the foxtail millet. The leaf folder (Figure 9) drastically affected the plant population of the research plot.

4.5.4 Bug

Bugs were also a serious pest observed in the field. The infestation of this insect caused low seed yield and low hundred grain weight due to hollow and unfilled seeds.

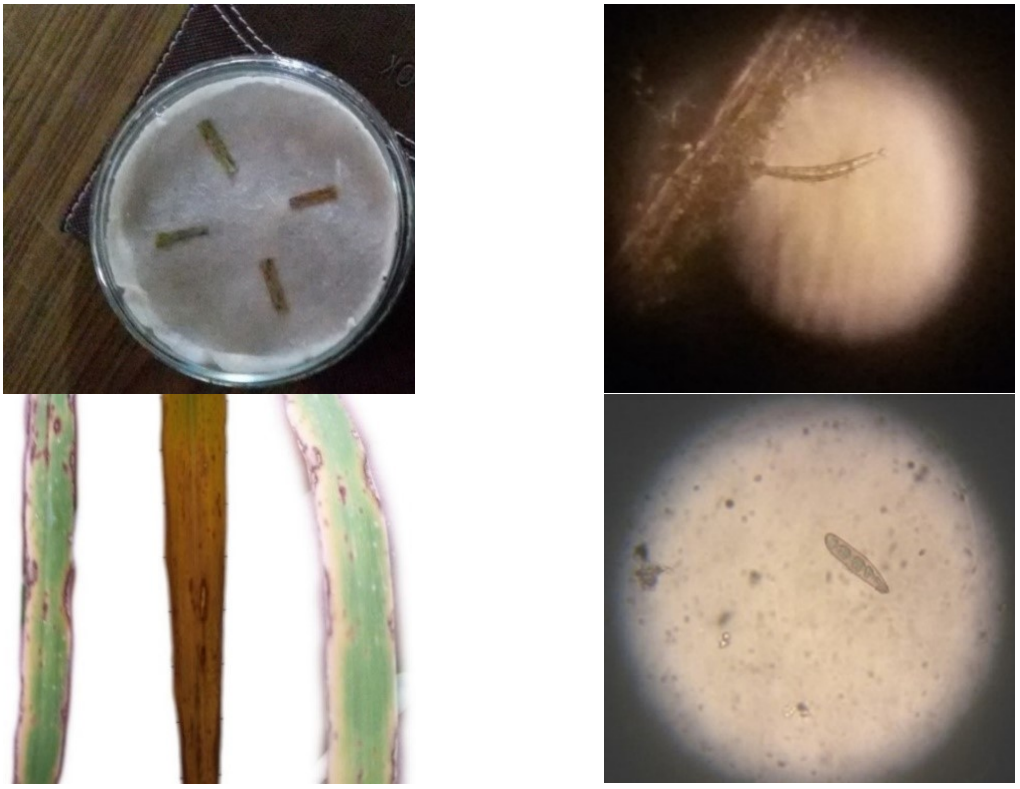


Figure 7: Conidia of *Helmintho sporium*, Symptoms of *Helmintho sporium*, conidiophore of helmintho sporium and placing of infected leaf in lab for confirmation of HLB

Figure 8: Larvae of stem borer of foxtail millet

Figure 9: Larvae of leaf folder and folded leaf

5 DISCUSSION

This study focused on the characterization of 10 foxtail millet accessions collected from several part of Nepal using different agro-morphological attributes evaluated at Rampur, Chitwan. Results showed significant variation of studied traits among the accessions, and it was possible to group accessions based on genetic similarity. High variation in agro-morphological traits among the foxtail millet accessions was reflected by wide ranges for most of the characteristics (Appendix 6). Phenotypic variation of the foxtail millet accessions was related to the diverse geographic origins. Most of studied traits (Appendix 2) are quantitative and the extensive variability among accessions is probably attributed to the genetic differences as well as the environment in which they were regenerated (Moriss, 2009).

Successful breeding of high yielding varieties depends on the yield contributing morphological traits and choosing small number of important traits having positive correlation. Flag leaf area, plant height, peduncle length and number of tillers per plant are an important morphological yield contributing traits that are positively correlated with yield per plant (Khaliq *et al*., 2008). The present study also suggested that high yielding accessions of foxtail millet may be selected by indirect selection of flag leaf length, flag leaf breadth, peduncle length, number of panicle per square meter. The accession Humla-149 showed best performance for most of the yield related traits and therefore can be relevant one for further evaluation in other locations of Nepal similar to Chitwan valley.

In a previous study by Reddy et. al. (2006), in which they had collected and characterized 1535 foxtail millet accessions from 26 countries that included 21 accessions from Nepal had higher grain yield than in the present study. The lower grain yields in this study might be due to the high infestation of disease and pests.

Amgai et al. (2011) studied five Nepalese foxtail millet accessions. In our study, grain yield was positively influenced by the traits like peduncle exertion, peduncle length, plant height, flag leaf length, stay green period, five panicle weight and number of panicle per square meter (Appendix 3, Figure 4). Similarly, the grain yield was positively contributed by flag leaf length and flag leaf breadth, whereas days to heading, and days to anthesis were negatively correlated with the grain yield indicating that early maturing materials had higher grain yields. These findings are in agreement with Amgai et. al. (2011).

The number of days between heading time and maturity time represents the grain filling period. Longer grain filing period with earlier heading and maturity is a desirable combination that breeders are interested to find. In this study, the correlation analyses revealed that those accessions which mature early i.e. shorter grain filling duration yielded higher than compared to the late maturing accessions. The accessions that matured late might have experienced heat stress during grain filling and therefore suffered from yield loss. Heat stress is considered to be one of the major environmental factors limiting crop yield as the stress induces many biochemical, molecular and physiological changes affecting the crop growth and grain yield negatively (Prasad et. al., 2008).

The Shannon Wiener index showed accessions were diverse in traits like panicle lodging and length of bristles of the panicles. The accessions varied least for growth habit. Tip of cotyledonary leaf had evenness of one i.e. the tip leaf type oval and pointed shape were equally distributed among the population. Similarly, anthocyanin pigmentation at leaf base was evenly distributed. Contrarily, growth habit of the accessions was uneven. Moreover, growth habit also had the lowest diversity index indicating that the accessions varied at minimum for this trait.

The observation of first cluster and the associations therein of high value for the traits like panicle exertion, panicle length, peduncle length, flag leaf length breadth ratio, panicle number per square meter and yield per plant hint that selection of accession from the first cluster can be worthwhile.

6 SUMMARY AND CONCLUSIONS

Foxtail millet (*Setaria italica* (L) P Beauv.) is considered as one of the major underutilized crops in Nepal, cultivated mainly in Karnali region of the country. The crop being in the under underutilized and neglected category, needs a major focus for the evaluation of local accession and genetic improvement of agronomic and quality traits. It is a hardy crop and considered as one of the potential crops for the future food security in the context of climate change.

An experiment was conducted in agronomy farm of Institute of Agriculture and Animal Science from July 31, 2015 to October 18, 2015 to characterize foxtail millet accession collected from different parts of Nepal. Twelve accessions were experimented in Randomized Complete Block Design with three replications. Of these, two accessions failed to emerge. Observations were taken for quantitative traits i.e. days to heading, days to anthesis, days to maturity, peduncle length, plant height, flag leaf length, flag leaf breadth, flag leaf length breadth ratio and stay green period and yield attributing traits i.e. panicle length, panicle exertion, number of panicle per square meter, hundred grain weight, five panicle weight and yield per plant. The mean performance was obtained and correlation analysis was performed between grain yield and other traits. Observations were also taken for qualitative traits i.e. tip of first leaf, anthocyanin at leaf base, lobe compactness, length of bristles, anthocyanin presence, leaf blade altitude, flag Leaf color, lobe in panicles, panicle lodging, inflorescence compactness, overall color, panicle anthocyanin, panicle shape and growth habit. Biodiversity index and evenness of these traits were also calculated for assessing the genetic diversity. Significant differences were observed among the accessions for many characters Based on quantitative and yield attributing traits, Humla-149 was considered the best performing accession.

The UPGMA clustering and PCA analysis revealed three distinct clusters of the studied accessions. Most closely related accessions were Co-1896 and Co-5645 and most distantly related accessions were Co-1896 and Humla-522.

The accessions were found most diverse for the panicle lodging trait and least diverse in terms of growth habit. The ten accessions were highly even of the trait tip leaf type and least even for growth habit.

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APPENDICES

Appendix 1: ANOVA of all the traits observed

Panicle length

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	7.8	3.898	1.073	0.36297
Accession	9	126.1	14.008	3.856	0.00715 **
Residuals	18	65.4	3.633		
Total	29	199.3	21.539		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Peduncle exertion

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	10.44	5.22	0.907	0.421339
Accession	9	289.99	32.22	5.602	0.000955 ***
Residuals	18	103.54	5.75		
Total	29	403.97	43.19		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Peduncle length

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
rep	2	5	2.49	0.251	0.78
accession	9	857.3	95.26	9.634	2.95e-05 ***
Residuals	18	178	9.89		
Total	29	1040.3	107.64		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Plant height

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	438	218.9	1.116	0.349
Accession	9	2451	272.3	1.388	0.264
Residuals	18	3532	196.2		
Total	29	6421	687.4		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Flag leaf length

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	35.3	17.63	0.973	0.397
Accession	9	189.2	21.02	1.159	0.375
Residuals	18	326.3	18.13		
Total	29	550.8	56.78		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Flag leaf breadth

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.0891	0.04456	0.473	0.63
Accession	9	0.8448	0.09386	0.997	0.476
Residuals	18	1.6949	0.09416		
Total	29	2.6288	0.23258		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Length breadth ratio

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	4.09	2.046	0.906	0.42187
Accession	9	103.89	11.544	5.11	0.00162 **
Residuals	18	40.66	2.259		
Total	29	148.64	15.849		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Stay green

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	13.9	6.93	0.446	0.6474
Accession	9	414.7	46.07	2.96	0.0239 *
Residuals	18	280.1	15.56		
Total	29	708.7	68.56		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Panicle weight

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	1.155	0.5776	0.619	0.549
Accession	9	13.395	1.4884	1.596	0.19
Residuals	18	16.79	0.9328		
Total	29	31.34	2.9988		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Panicle number per m^2

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	304	151.9	0.581	0.5693
Accession	9	6959	773.3	2.959	0.0239 *
Residuals	18	4704	261.3		
Total	29	11967	1186.5		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Days to heading

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	5.1	2.53	0.263	0.772
Accession	9	1644.3	182.7	18.944	1.95e-07 ***
Residuals	18	173.6	9.64		
Total	29	1823	194.87		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Days to anthesis

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	5.3	2.63	0.411	0.669
Accession	9	1403.2	155.91	24.319	2.67e-08 ***
Residuals	18	115.4	6.41		
Total	29	1523.9	164.95		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Days to maturity

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	7.4	3.7	0.416	0.666
Accession	9	1267.9	140.87	15.855	7.76e-07 ***
Residuals	18	159.9	8.89		
Total	29	1435.2	153.46		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Hundred grain weight

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.00152	0.0007624	0.427	0.659
Accession	9	0.01419	0.0015766	0.883	0.557
Residuals	18	0.03213	0.001785		
Total	29	0.04784	0.004124		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Yield per plant

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.0006	0.000302	0.132	0.87688
Accession	9	0.07648	0.008498	3.724	0.00847 **
Residuals	18	0.04107	0.002282		
Total	29	0.11815	0.011082		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix 2: Mean of traits of 10 foxtail millet accessions under study

Treatments	Panicle Exertion Cm	Panicle length cm	Peduncle length Cm	Plant Height cm	Flag Leaf Length Cm	Flag Leaf Breadth cm	Length Breadth Ratio	Stay Green Days	Five Panicle Weight gm	Panicle number per m^2	Days to heading	Days to anthesis	Days to maturity	Hundred grain weight
Accessions														
Co-1896	10.111 ^{b}	9.222 ^{abcd}	22.750 ^{abc}	66.944	17.444	1.200	14.628 ^{abc}	26.000 ^{a}	2.266	61.000 ^{ab}	43.666 ^{cd}	47.333 ^{bc}	71.333 ^{ab}	0.08
Co-3474	5.277 ^{c}	10.944 ^{abc}	14.611 ^{d}	59.666	17.655	1.222	14.244 ^{abcd}	19.67^{abcd}	1.366	46.67 ^{abc}	55.000 ^{a}	57.666 ^{a}	76.666 ^{a}	0.053
Co-5148	16.111 ^{a}	7.667 ^{cd}	27.766 ^{a}	61.877	20.111	1.277	15.893 ^{a}	22.000 ^{abc}	2.353	56.00^{abc}	35.666 ^{e}	39.333 ^{d}	60.666 ^{c}	0.068
Co-5645	9.611 ^{b}	9.111 ^{abcd}	19.055 ^{bcd}	75.555	19.944	1.611	12.462 ^{bcde}	23.34 ^{ab}	3.000	61.000 ^{ab}	45.666 ^{bc}	48.333 ^{b}	70.000 ^{b}	0.049
Humla-149	13.077 ^{ab}	11.978 ^{a}	25.100 ^{a}	63.333	22.000	1.611	13.707 ^{abcd}	20.67 ^{abc}	1.872	71.666 ^{a}	34.666 ^{e}	39.666 ^{d}	59.000 ^{c}	0.012
Humla-150	10.283 ^{b}	7.300 ^{cd}	18.616 ^{cd}	49.277	19.111	1.255	15.339 ^{ab}	12.666 ^{d}	0.868	35.666 ^{bc}	39.666 ^{de}	43.333 ^{cd}	58.000 ^{c}	0.068
Humla-164	10.194 ^{b}	11.806 ^{ab}	16.638 ^{d}	64.250	18.855	1.555	12.251 ^{cde}	15.000 ^{cd}	1.400	33.000 ^{bc}	49.666 ^{ab}	53.000 ^{a}	70.000 ^{b}	0.046
Humla-213	8.611 ^{bc}	5.777 ^{d}	17.222 ^{cd}	53.777	13.511	1.166	11.621 ^{de}	18.00 ^{bcd}	1.033	26.000 ^{c}	53.000 ^{a}	56.000 ^{a}	73.666 ^{ab}	0.046
Humla-522	5.277 ^{c}	6.556 ^{d}	8.888 ^{e}	42.722	14.000	1.333	9.741 ^{e}	17.67^{bcd}	1.000	25.666 ^{c}	53.000 ^{a}	55.000 ^{a}	73.000 ^{ab}	0.052
Humla-523	11.744 ^{b}	8.211 ^{bcd}	24.466 ^{ab}	52.844	18.666	1.222	15.333 ^{ab}	18.34^{bcd}	1.248	41.34^{abc}	36.333 ^{e}	39.666 ^{d}	61.666 ^{c}	0.056
Grand Mean	10.030	8.857	19.511	59.025	18.130	1.345	13.522	19.333	1.640	45.800	44.633	49.933	67.400	0.064
F-test	0.000 ***	0.007**	0.000 ***	0.264	0.375	0.476	0.001 **	0.023 *	0.190	0.023 *	0.000***	0.000***	0.000***	0.557
LSD	4.114	3.269	5.393				2.578	6.767		27.729	5.327	4.343	5.113	0.072
CV (%)	23.911	21.520	16.115	23.733	23.485	22.805	11.114	20.405	58.857	35.294	6.957	5.282	4.422	65.780

Appendix 3: Pearson's correlation coefficient among different traits of accessions of foxtail millet under study

	Days to Heading	Days to Anthesis	Days to Maturity	Panicle Length (cm)	Panicle Exertion (cm)	Peduncle Length (cm)	Plant Height (cm)	Flag Leaf Length (cm)	Flag Leaf Breadth (cm)	Flag Leaf Length Breadth Ratio	Stay Green Period	Five Panicle Weight (gm)	No of Panicle per square metre	100 grain weight (gm)	Yield per plant (gm)
Days to Heading	1														
Days to Anthesis	0.979**	1													
Days to Maturity	0.847**	0.859**	1												
Panicle Length (cm)	-0.159	-0.102	-0.022	1											
Panicle Exertion (cm)	-0.772**	-0.752**	-0.639**	0.255	1										
Peduncle Length (cm)	-0.769**	-0.781**	-0.601**	0.242	0.832**	1									
Plant Height (cm)	-0.233	-0.214	0.020	0.637**	0.474**	0.479**	1								
Flag Leaf Length (cm)	-0.591**	-0.576**	-0.393*	0.586**	0.599**	0.529**	0.698**	1							
Flag Leaf Breadth (cm)	-0.275	-0.249	-0.114	0.573**	0.295	0.212	0.703**	0.799**	1						
Flag Leaf Length Breadth Ratio	-0.590**	-0.599**	-0.478**	0.151	0.576**	0.568**	0.181	0.508**	-0.099	1					
Stay Green Period	-0.205	-0.163	0.275	0.209	0.201	0.269	0.457*	0.214	0.178	0.144	1				
Five Panicle Weight (gm)	-0.318	-0.317	-0.011	0.464**	0.476**	0.498**	0.887**	0.686**	0.663**	0.176	0.541**	1			
No of Panicle per square metre	-0.553**	-0.515**	-0.286	0.517**	0.372*	0.534**	0.589**	0.645**	0.534**	0.291	0.500**	0.648**	1		
100 grain weight (gm)	-0.373*	-0.334	-0.221	0.049	0.111	0.155	-0.093	-0.051	-0.116	0.129	0.297	-0.139	0.237	1	
Yield per plant (gm)	-0.567**	-0.600**	-0.299	0.361	0.626**	0.745**	0.649**	0.625**	0.446*	0.370*	0.507**	0.796**	0.656**	-0.070	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 4: Statistics of Multivariate analysis of accessions under study

Eigen analysis of the Correlation Matrix										
Eigen value	6.1904	1.9704	0.939	0.4917	0.2667	0.079	0.0373	0.0255	0.0002	0
Proportion	0.619	0.197	0.094	0.049	0.027	0.008	0.004	0.003	0	0
Cumulative	0.619	0.816	0.91	0.959	0.986	0.994	0.997	1	1	1

Variable	PC 1	PC 2	PC 3
Panicle Exertion	0.361	0.146	0.063
Panicle length	0.099	-0.34	-0.862
Peduncle length	0.383	-0.003	0.086
Length Breadth Ratio	0.304	0.115	-0.112
Stay Green	0.157	-0.583	0.418
Panicle/m2	0.306	-0.417	-0.116
Days to heading	-0.381	-0.191	-0.002
Days to anthesis	-0.377	-0.2	-0.043
Days to maturity	-0.316	-0.398	0.125
Yield per plant	0.339	-0.318	0.166

Cluster Centroids				
Variable	Cluster 1	Cluster 2	Cluster 3	Grand centroid
Panicle Exertion	12.2275	7.3398	11.0135	10.0296
Panicle length	9.4945	8.7707	7.7555	8.8572
Peduncle length	23.6677	14.3398	21.541	19.5112
Length Breadth Ratio	14.1725	11.9643	15.336	13.5219
Stay Green	22.9997	17.583	15.4995	19.333
Panicle/m2	62.4165	32.833	38.4995	45.7997
Days to heading	39.916	52.6665	37.9995	44.6329
Days to anthesis	43.6662	55.4165	41.4995	47.933
Days to maturity	65.2498	73.333	59.833	67.3997
Yield per plant	0.1463	0.0457	0.0845	0.0937

Distances Between Cluster Centroids

	Cluster 1	Cluster 2	Cluster 3
Cluster1	0		
Cluster2	37.24	0	
Cluster3	26.007	26.5567	0

Appendix 5: Statistics of Qualitative traits of accession of foxtail millet under study

Tip of first leaf	Frequency	Percent
Pointed	15	50.0
Pointed to Round	15	50.0
Total	30	100.0

Anthocyanin Presence at Zadoks 15 stage	Frequency	Percent
Absence	18	60.0
Presence	12	40.0
Total	30	100.0

Anthocyanin at leaf base	Frequency	Percent
Absence	17	56.7
Presence	13	43.3
Total	30	100.0

Growth Habit	Frequency	Percent
Erect	26	86.7
Semi erect	4	13.3
Total	30	100.0

Overall color	Frequency	Percent
Light green	5	16.7
Medium green	20	66.7
Dark green	5	16.7
Total	30	100.0

Leaf blade altitude	Frequency	Percent
Semi erect	7	23.3
Horizontal	16	53.3
Drooping	7	23.3
Total	30	100.0

length of bristles	Frequency	Percent
Short	7	23.3
Medium	10	33.3
Long	13	43.3
Total	30	100.0

panicle shape	Frequency	Percent
Conical	3	10.0
Cylindrical	24	80.0
Duck mouth	3	10.0
Total	30	100.0

Panicle anthocyanin	Frequency	Percent
Absence	25	83.3
Presence	5	16.7
Total	30	100.0

lobe in panicles	Frequency	Percent
Absence	8	26.7
Presence	22	73.3
Total	30	100.0

Panicle lodging	Frequency	Percent
Erect	6	20.0
Semi erect	16	53.3
Horizontal	6	20.0
Drooping	2	6.7
Total	30	100.0

Inflorescence compactness	Frequency	Percent
Loose	3	10.0
Medium	15	50.0
Compact	10	33.3
Spongy	2	6.7
Total	30	100.0

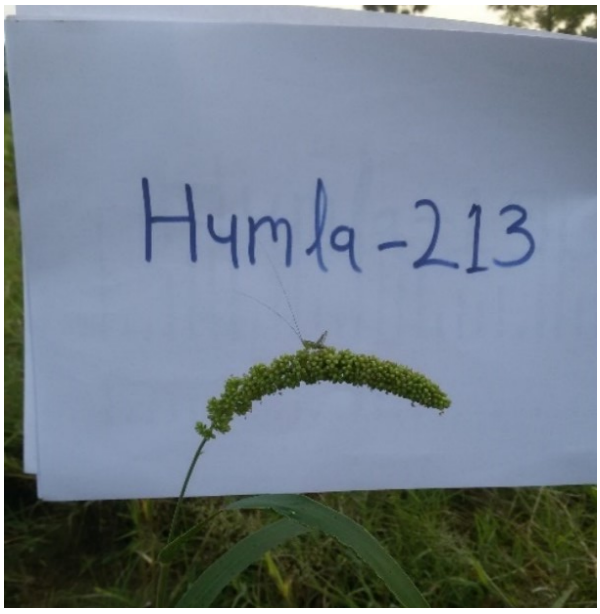
Flag Leaf color	Frequency	Percent
Light green	11	36.7
Medium green	15	50.0
Dark green	4	13.3
Total	30	100.0

Appendix 6: Characterization of Agro-morphological traits of accessions of foxtail millet under study

Accession	Tip of leaf (1=pointed, 2=pointed to round)	Anthocyanin presence at Zadok 15 (1=Presence, 0=absence)	overall color (1-lg,2-mg,3-dg)	Growth habit (1-e,2-se,3-spr)	Anthocyanin at leaf base (1-presence, 0-absence)	Anther color (0- pink)	Leaf blade altitude (1 erect, 2 semi erect, 3 horizontal and 4 drooping)	Length of bristles (1-very short,2-medium,3-long)
Co-1896	1	0	2	1	0	0	3	3
Co-3474	2	0	2	1	0	0	3	3
Co-5148	1	1	2	1	1	0	4	2
Co-5645	2	0	3	1	0	0	2	2
Humla-149	2	1	1	1	1	0	4	2
Humla-150	2	1	2	1	1	0	3	2
Humla-164	1	0	2	1	1	0	3	3
Humla-213	2	0	2	1	0	0	3	1
Humla-522	1	0	2	1	1	0	3	2
Humla-523	1	1	2	1	1	0	3	3

Accession	Panicle anthocyanin (1-presence ,0-absence)	Panicle shape (1 conical, 2 spindle, 3 cylindrical, 4 club, 5 duck mouth, 6 cat foot and 7 branched)	Length of bristles (1 short, 3 medium and 5 long)	Lobe in panicles 1 present, 0 absent	Lobe compactness 3 loose, 5 medium, 7 compact, 9 spongy)	Inflorescence compactness Lobe compactness 3 loose, 5 medium, 7 compact, 9 spongy	Flag leaf color 1 light green, 2 medium green, 3 dark green	Panicle anthocyanin (1-presence ,0-absence)
Co-1896	0	3	3	1	7	7	2	0
Co-3474	0	3	3	1	3	5	2	0
Co-5148	1	3	2	1	3	3	1	1
Co-5645	0	3	2	1	5	9	2	0
Humla-149	0	3	2	1	5	5	2	0
Humla-150	0	3	2	0		5	2	0
Humla-164	0	3	3	1	3	5	3	0
Humla-213	0	3	1	0		7	2	0
Humla-522	0	3	1	0		5	1	0
Humla-523	0	3	3	1	3	5	1	0

SOME GLIMPSES OF THE RESEARCH



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