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Nutrients in finger millet and soil at different elevation gradients in Central Nepal



Dol Raj Luitel^{1,2*} , Mohan Siwakoti¹ and Pramod K. Jha^{1*}

Abstract

Background: Finger millet, a subsistence food crop, is a unique cereal with high nutritional quality particularly in hilly regions in Nepal. Hence, grain nutrients (protein, calcium, and iron percent) of ten different landraces of finger millet and soil quality (SOC, N, P and K) at different altitudes in central Nepal were analyzed.

Methods: Triplicate finger millet grain samples were collected from ten local landraces cultivated in randomized complete block design (RCBD) experiments at three different elevations (365 m, 1040 m and 1856 m) under the farmer management system for 2 years 2016 and 2017. Similarly, triplicate soil samples were collected from each experiment plot of different elevation. Kjeldahl method was used to determine grain protein and atomic absorption spectrophotometry method was used to determine calcium and iron. Soil nitrogen (N) was estimated by Kjeldahl method, the available phosphorous (P) by a modified Olsen's method, potassium by Hanway and Heidel method and pH by using digital pH meter.

Results: The protein calcium and iron content in finger millet grain was significantly different ($P < 0.05$) among the local landraces and elevation levels. In all landraces of finger millet, the grain protein, calcium and iron content was found to increase along the increasing altitude. An average increase of 3.13% protein was found when altitude increased from 365 to 1856 m. However, only 2.04% and 1.09% of average grain protein increased as elevation increased from 365 m to 1040 m and 1040 m to 1856 m, respectively. The average Ca content increased by 0.47% when altitude increased from 365 to 1856 m. Similarly, the average Ca increased by 0.21% and by 0.26% as altitude increased from 365 m to 1040 m, and 1040 m to 1856 m, respectively and an average 0.33% Fe increase was found from 365 to 1856 m altitude. An increase of 0.11% and 0.21% of Fe was found from 365 to 1040 m and from 1040 to 1856 m, respectively. Soils at all experimental sites were acidic. The SOC, P, K of soil also increased with increasing altitude.

Conclusions: This study demonstrated the relationship among nutrients in finger millet (proteins, Ca and Fe), soil components (SOC, N, P and K), and altitudes, with respect to ambient climate. The grain nutrients (Nitrogen, Ca and Fe) of finger millet at higher altitudes were found higher than lower altitudes. Similarly, the temperature and grain nutrients showed strong negative correlation with growing season temperature. This study reveals relations of finger millet nutrients with climatic and soil conditions which are crucial to design the promotion policies of nutrient rich local crops in Nepal.

Keywords: Altitudes, Iron, Nitrogen, Nutrient phosphorus, Potassium, Soil organic carbon

Background

Developing countries, particularly in Asia and Africa, experience major food deprivation (Vetriventhan and Upadhyaya 2019) and nutrition insecurity (Kumssa et al. 2015). Three main cereals—rice (*Oryza sativa* L.), wheat

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(*Triticum aestivum* L.) and maize (*Zea mays* L.)—play a major role in human energy intake (Cakmak and Kutman 2018) and food security (Ceasar et al. 2018); however, crops like finger millet have nutritional properties superior to these crops that can boost nutritional security (Puranik et al. 2017) in developing countries like Nepal. Africa and Asia produce about 55% and 42%, respectively, of the world's finger millet (Bhagavatula et al. 2013). Finger millet is the fourth most important cereal crop in Nepal after rice, wheat, and maize in terms of area and production (MOAD 2017). In 2017, there was a deficit of about 71,400 tons of food in 23 hilly and mountain districts of Nepal where finger millet, barley, and buckwheat crops are grown under rain-fed conditions (MALMC 2018). These districts are vulnerable to food and nutritional insecurity, which may increase due to climate change. Climate change is a global phenomenon; however, Nepal is experiencing higher rates in comparison to global average temperature rise in the mountains (Shrestha et al. 2012). It is well known that an increase in temperature is a threat to human nutrition and food production (Myers et al. 2017; Smith and Myers 2018).

The finger millet grain is rich in protein, calcium, dietary fiber, and minerals (FAO 1991; Mbithi et al. 2000; Obilana and Manyasa 2002; FAO 2005; Dayakar et al. 2016; Wafula et al. 2018), playing crucial role of providing food and nutrition in its growing regions (Saleh et al. 2013). Finger millet grain contains higher calcium (Ca) [0.34%] (Gupta et al. 2017; Ceasar et al. 2018), iron (Fe) (Kumar et al. 2016) and protein (Sharma et al. 2017) than other major food crops such as rice, wheat and maize. Different literatures revealed the nutritional value of finger millet growing in India (Arjun et al. 2014; Upadhyaya et al. 2011; Singh and Srivastava 2006), Ethiopia (Admassu et al. 2009), and in Kenya (Wafula et al. 2018); however, to our knowledge, no nutritional analysis has been done on finger millet landraces along the elevation gradient in Nepal. Under these scenarios, it was important to determine the nutrient qualities of local landraces of finger millet at different altitudes in the context of local climate and soil conditions.

Methods and materials

Study area

The study area is located in Chitwan Annapurna Landscape (CHAL), Central Nepal, between 27°35' and 29°33' N latitude and 82°88' and 85°80' E longitude, covering an area of 32,057 km², with an elevation ranging from 200 to 8091 m. CHAL includes all or part of 19 districts (Mustang, Manang, Gorkha, Rasuwa, Nuwakot, Dhading, Lamjung, Tanahu, Syangja, Kaski, Palpa, Parnat, Baglung, Myagdi, Gulmi, Arghkhachi, Makwanpur, Chitwan and Nawalparasi) (Fig. 1), which covers about

22% land area of Nepal (MoFSC 2015). The area is a traditional subsistence-based agricultural system integrated with crops, livestock, and fodder trees as the main agro-ecological features. The major crops in the mountains and mid-hill parts of the regions are maize, wheat, finger millet, barley, and buckwheat, whereas in the inner Terai regions, rice, maize, wheat, finger millet, and potatoes are cultivated.

A wide range of climatic conditions occur in CHAL. It ranges from a subtropical humid climate in the lowlands (Chitwan and Nawalparasi districts) to alpine conditions in the high mountains, including a cold, dry climate in the trans-Himalayan parts of Manang and Mustang districts. The average minimum and maximum temperatures in CHAL vary according to altitude. The mean temperature of Siwalik [lower tropical climatic region (LTCR)] is more than 25 °C, followed by 20 °C in the middle hills [lower subtropical climatic region (LSTCR), and between 10 and 20 °C in the high mountains [upper subtropical climatic region (USTCR)] (MoE 2011) (Table 1). The average annual rainfall ranges from 165 mm at Lomanthang (Mustang) in the northern part of CHAL to 5244 mm at Lumle (highest rainfall in the mid-hills) located near Pokhara, Kaski (DHM 2017). Orographic effects cause high spatial variation in precipitation across the landscape. The overall climate of different regions of CHAL is presented in Table 1.

Nutrient analysis

Ten local landraces of finger millet [KLE-236, KLE-158, KLE-158, ACC#433-1, NE-1703-34, Dolakha local, Okhale-1, Kabre-1, Kabre-1, Kabre-2, Dalle-1] were collected from Hill Crop Research Stations (HCRS) (Kavre, Dolakha) for cultivation in farms at three different altitudes in CHAL [Sankhadev Nawalparasi (365 m), Dumrebhanjyang, (1040 m) and Kokhe (1856 m)] of Syangja districts falling in two ecological regions [lower tropical climatic region (LTCR) and upper tropical to sub-tropical climatic region (UTSCR)] (Fig. 2). The experiment was laid out in RCBD on 10 landraces (treatments) with three replications (blocks) for 2 years in 2016 and 2017.

Triplicate grain samples of each local landrace were collected in each year for analysis of nutrient quality from three elevation levels and these samples were used to analyze their nutrient quality in the laboratory. The laboratory analysis was done at the Agricultural Technological Centre (ATC), Lalitpur.

The nitrogen content was determined by Kjeldahl method as prescribed by Horneck and Miller (1988). The protein content of grain was calculated by multiplying nitrogen percent by Johns factors 6.25 (Kjeldahl determination). Iron, Potassium, and Calcium content were

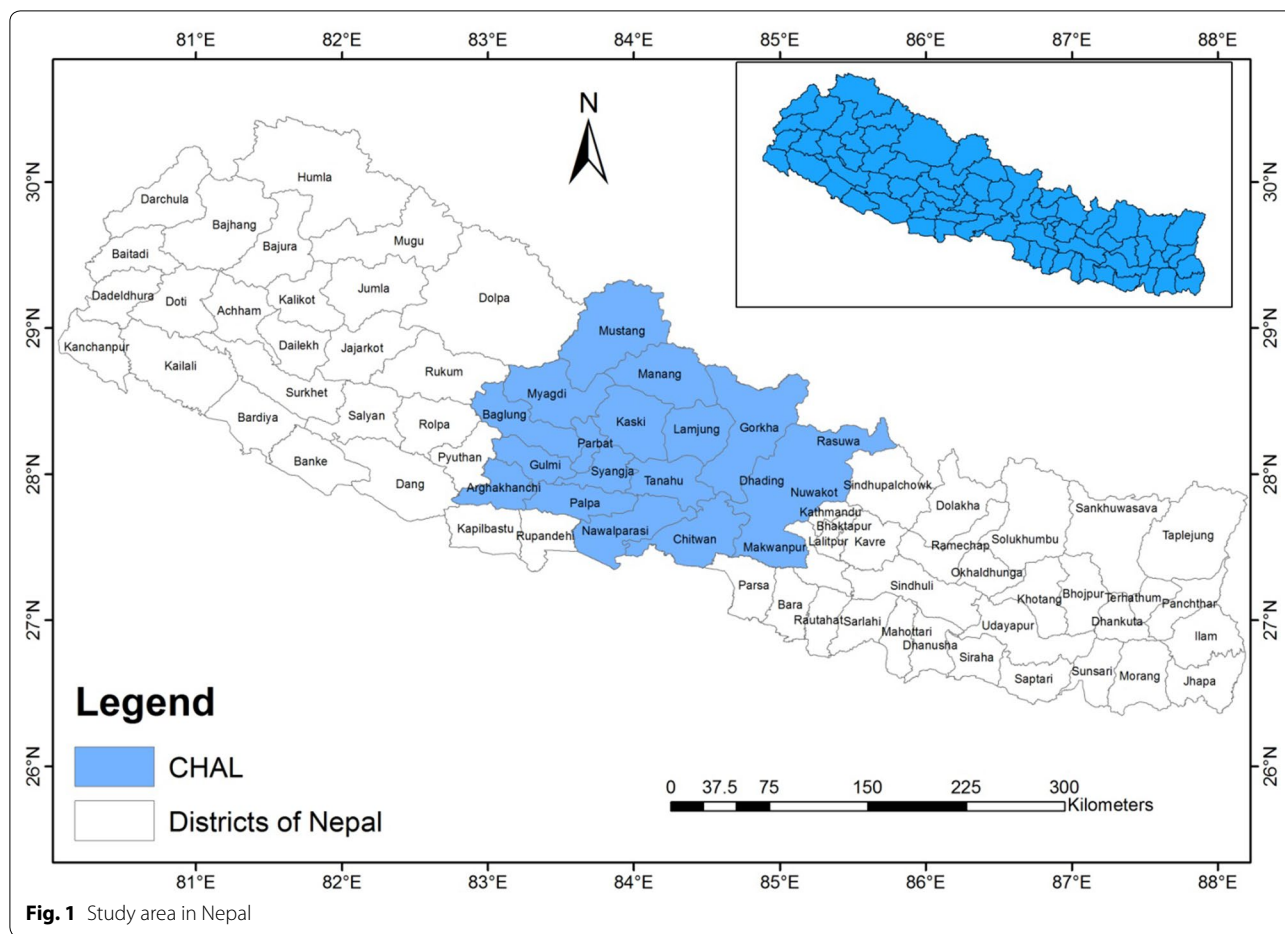


Fig. 1 Study area in Nepal

Table 1 Climatic conditions of experimental sites in CHAL Source: WECS (2011), DHM (2017)

Sites (elevation m)	Physiographic regions	Climatic region	Mean annual temperature (°C)	Average annual precipitation (mm)
365	Siwaliks	Lower tropical CR	20–25	1100–3000
1040	Mid-hills	Lower subtropical CR	10–20	275–2300
1856	High mountains	Upper sub tropical CR	< 3–10	150–200

analyzed by using atomic absorption spectrophotometry method described in Hilu and Barbeau (1993).

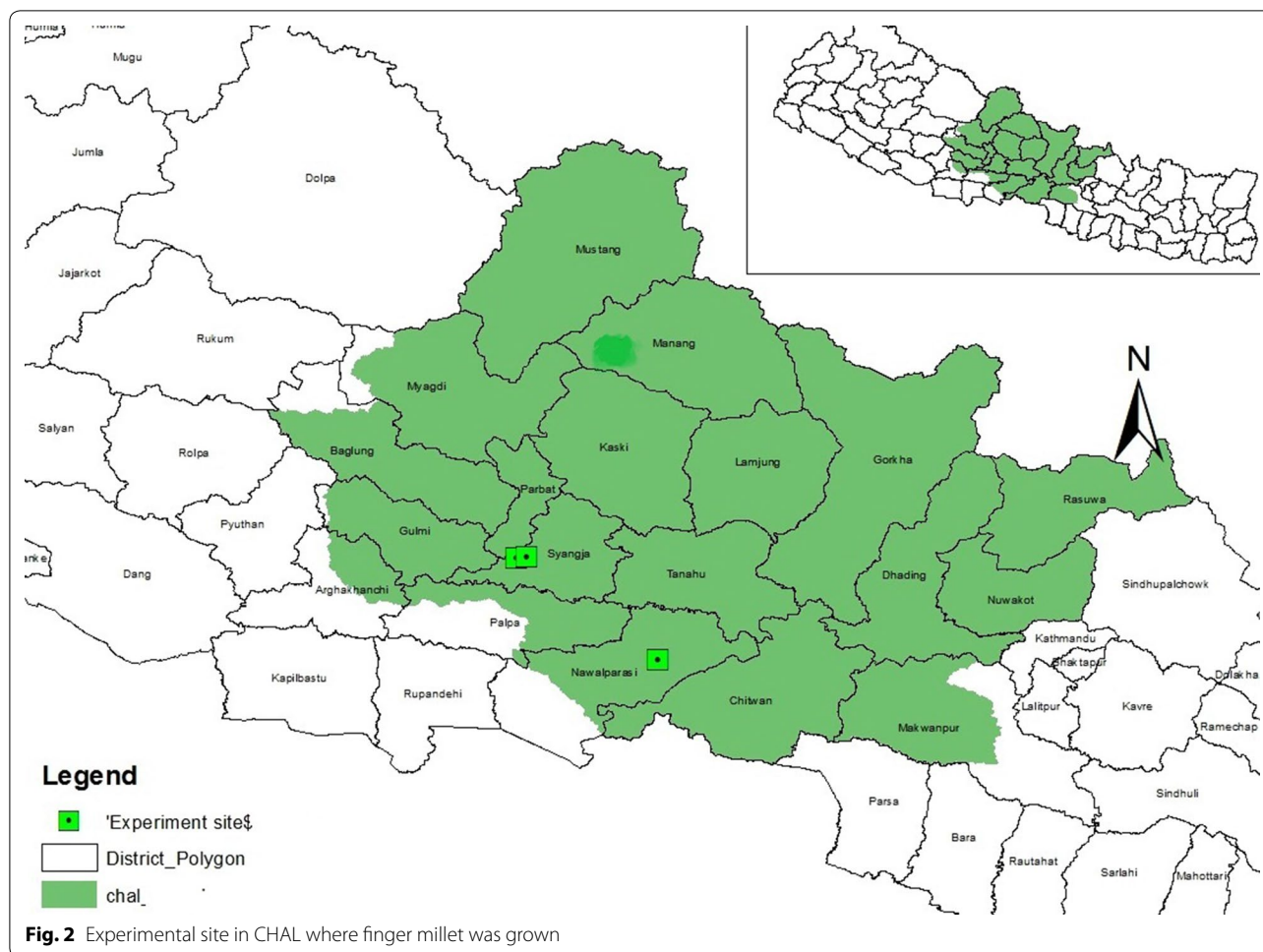
Soil analysis

Sample collection and analysis

Triplicate composite soil samples (a single sample constitutes the mixture of soil from all 10 individual plots within block) were collected from the plough layer surface (0–15 cm) for the purpose of quantifying soil chemical properties. The soil samples were collected just before the transplantation of finger millet seedlings. The samples were properly air dried and kept in zipper

plastic bags with proper labelling and brought to Ecology Laboratory-Central Department of Botany, Tribhuvan University. The soil chemical analyses were done in the Laboratory of Forests Research and Training Centre (FRTC), Babar Mahal, under the Ministry of Forests and Environment. The pH, soil organic carbon, total nitrogen, available phosphorus and potassium were analyzed by following the methods prescribed in Zobel et al. (1987).

Soil organic carbon (SOC) was determined by following Walkley and Black (1934), total nitrogen (N) was estimated by Kjeldahl method (Bremner and Mulvaney 1982), the available phosphorous (P) was determined by



a modified Olsen's method (Olson and Sommers 1982), potassium by Hanway and Heidel method (Hanway and Heidel 1952), and pH using a digital pH meter with 1:1 soil water ratio (McLean et al. 1982).

Statistical analysis

The descriptive statistics (mean, standard deviation, standard errors) of data were computed through Microsoft excel 2010. The Shapiro–Wilk normality test was applied to test normality of data. The grain nutrients (Protein, Calcium and iron) and soil components data showed the normal distribution. The parametric test—ANOVA was used to examine whether there was significant difference in nutrients at 5% level of significance according to altitude in R package version 3.4.4 (R Core Team 2013).

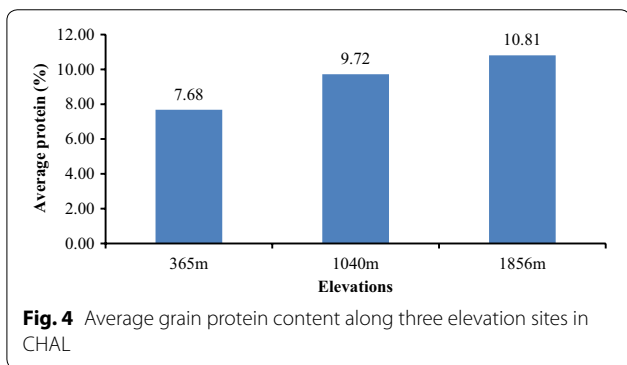
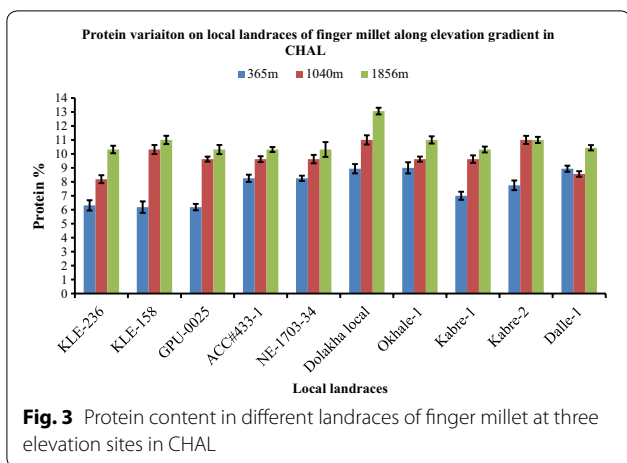
Results

Protein

The protein content in finger millet grain was significantly different ($P < 0.05$) among the local landraces

and elevation levels. In all landraces of finger millet, the grain protein content was found to increase along the increasing altitude. The highest protein content (9%) was found on Okhale-1 at 365 m followed by Dalle-1, Dolakha local, ACC#433-1, NE 1703-34, Kabre-2, Kabre-1, GPU-0025, KLE-158, and KLE 236 with the least at 6.31%. Thus, range of protein was between 6.31 and 9%. At 1040 m altitude, the range of protein was between 8.19 and 11% having highest grain content on Dolakha local (11%) and least on KLE-236 (8.19%). However, at 1856 m altitudes, the range grain protein was between 10.31 and 13.06% with highest on Dolakha local (13.06%) and least on five local landraces (KLE-236, GPU-0025, ACC#433-1, NE1703-34 and Kabre-1) (Fig. 3). The grain protein among local landraces showed great variation but successively increases the grain nutrient percent as elevation increases.

The average grain protein of 2.04% and 1.09% increased as elevation from 365 m to 1040 m and 1040 m to 1856 m, respectively (Fig. 4).



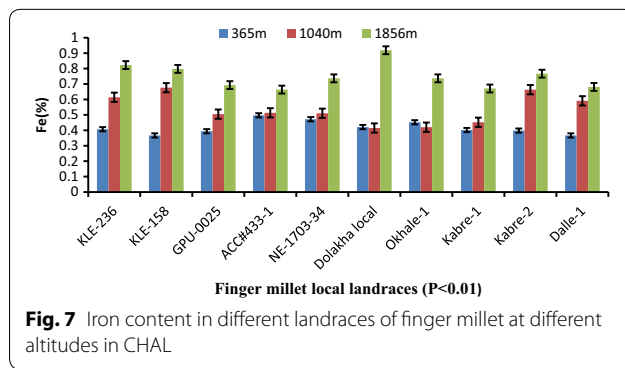
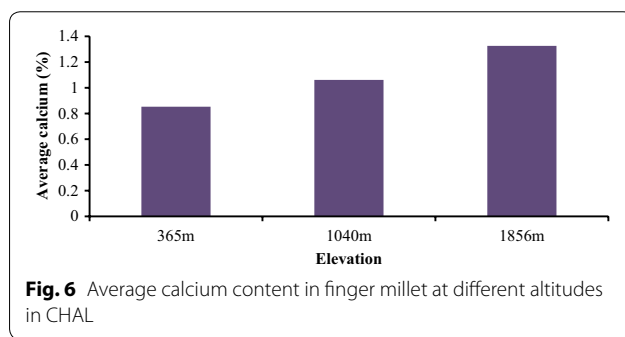
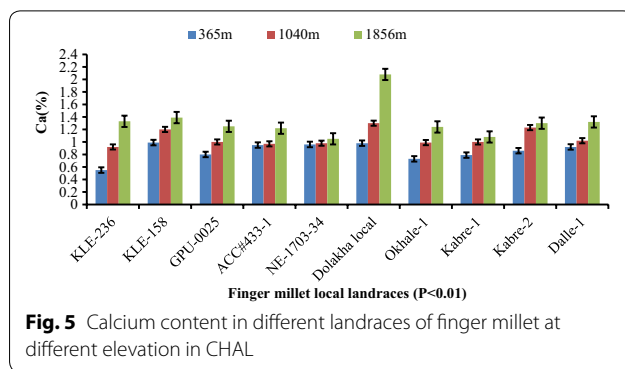
Calcium

The calcium (Ca) content of finger millet grain significantly varied ($P < 0.05$) among the local landraces at different altitudes. In all landraces, a similar increasing trend of calcium in grains was found at different altitudes. At altitude 365 m, the maximum Ca was found in KLE158 (0.99%) and the least in KLE-236 0.55% landraces. Similarly, at 1040 m, the range of Ca was found between 0.92% in KLE-236 and 1.23% in landrace Kabre-2. The highest Ca was found in Dolakha local (2.08%) at 1856 m altitude and least on Kabre-1 (1.08%) (Fig. 5).

Among ten local landraces, the average Ca content increased by 0.47% when altitude increased from 365 to 1856 m. Similarly, the average Ca increased by 0.21% and by 0.26% as altitude increased from 365 m to 1040 m, and 1040 m to 1856 m, respectively (Fig. 6).

Iron

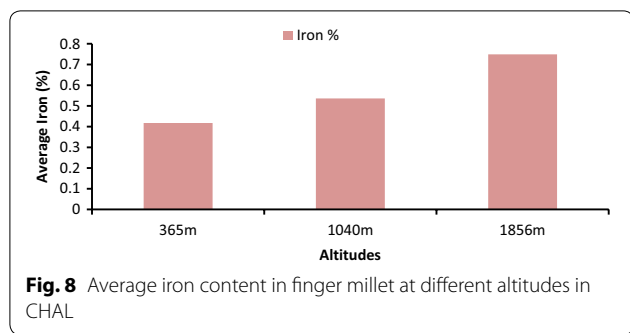
The iron (Fe) content in finger millet grain significantly ($P < 0.05$) varied in different landraces at different elevation levels. A similar trend in iron content was observed in finger millet increasing at higher altitude (Fig. 7). An



average 0.33% Fe increase was found from 365 to 1856 m altitude. An increase of 0.11% and 0.21% of Fe was found from 365 to 1040 m and from 1040 to 1856 m, respectively, (Fig. 8).

Soil chemical properties

Soils at all experimental sites were acidic. The acidic nature of soil also increased with increasing altitude. The average soil pH was 6.1 ± 0.05 , 6.0 ± 0.2 , and 5.65 ± 0.05 , respectively, at 365 m asl, 1040 m, and 1856 m altitudes (Table 2). Elevation wise, analysis of soil organic carbon (SOC), nitrogen (N), available phosphorus (P), and exchangeable potassium (K) is also presented in Table 2.



The soil organic carbon percent was highest (4.03%) at 1856 m altitude.

Nitrogen and available phosphorus content in soil samples had a specific pattern, i.e., as elevation increased, the soil components also increased at 127.57 ± 23.02 , 170.32 ± 4.25 , and 321.76 ± 12.81 ppm nitrogen, and 5.63 ± 0.28 , 12.71 ± 0.28 , and 30.14 ± 69 at 365 m, 1040 m, and 1856 m altitudes, respectively. The exchangeable potassium was also found highest (291.29 ± 5.75) at 1856 m (Table 2).

Discussion

Protein

Protein is the second most important component after carbohydrates in the grains of finger millet. Different literature indicates nearly 7% protein content in grains of finger millet; however, variation from 5.6 to 12.7% exists (Arjun et al. 2014). Singh and Srivastava (2006) analyzed 16 varieties of finger millet and found

that grain protein ranged from 4.88 to 15.58%, with a mean value of 9.72%. Similarly, Vadivoo et al. (1998) analyzed 36 genotypes of finger millet and found that it ranged from 6.7 to 12.3% with a mean of 9.7%. Bachar et al. (2013) reported that finger millet has nearly 7% protein, while others reported 11% grain protein in finger millet (Amadou et al. 2013). Chethan and Malleshi (2007) reported that finger millet contains about 5–8% protein. The proximate protein composition of ten cultivars (two wild and eight originated in different areas of the world) were analyzed by Barbeau and Hilu (1993), reporting that the grain protein ranged from 7.5 to 11.7%. Similarly, from a study of different local landraces of finger millet in Ethiopia, the grain protein content of finger millet was found to be between 6.26 and 10.5% (Admassu et al. 2009). Chandra and Chandra (2016) mentioned in a literature review that the protein content in finger millet is 8.3%. All of these findings indicate that the range of protein among local landraces varies significantly, which is consistent with this study. However, the grain protein variation along the elevation gradient had not been analyzed in Nepal or elsewhere. In the case of Central Nepal, grain protein among ten landraces showed a very clear pattern that elevation increase has a strong positive correlation with protein content (Table 3). The average (of the 10 local landraces) protein content of finger millet grain at 365 m, 1040 m, and 1856 m was found to be 7.31%, 9.7%, and 10.8%, respectively. Among the studied landraces, Dolakha local at 1856 m elevation showed the highest protein content (13.1%). These findings are

Table 2 Variation on soil chemical properties of finger millet field along altitudes gradient

Elevation (m)	SOC%	N (ppm)	P (ppm)	K (ppm)	pH
365	1.91 ± 0.03	127.57 ± 23.02	5.63 ± 0.28	212.49 ± 2.7	6.1 ± 0.05
1040	1.88 ± 0.008	170.32 ± 4.25	12.71 ± 0.28	72.88 ± 3.37	6.0 ± 0.2
1856	4.03 ± 0.04	321.76 ± 12.81	30.14 ± 69	291.29 ± 5.75	5.65 ± 0.05

Table 3 Correlation (r) between grain protein percent and soil component at different altitudes in Central Nepal

	Alt	SOC	N (ppm)	P (ppm)	K (ppm)	Protein	Ca	Fe
Alt	1.00							
SOC	0.86	1.00						
N (ppm)	0.95	0.98	1.00					
P (ppm)	0.97	0.96	1.00	1.00				
K (ppm)	0.36	0.78	0.63	0.57	1.00			
Protein	0.98	0.76	0.88	0.92	0.19	1.00		
Ca	0.83	1.00	0.96	0.94	0.82	0.72	1.00	
Fe	0.78	0.99	0.94	0.91	0.86	0.66	1.00	1.00

consistent with other similar studies, but grain protein at higher altitudes is greater than lower elevations.

The soil quality (SOC, N, P) showed strong correlation with altitudes i.e. with increasing altitude, there was an increase in all soil nutrient concentrations except K. The correlation between protein percent of finger millet grain and soil phosphorus and nitrogen showed a strong correlation with $r=0.92$. Soil organic carbon also showed strong relation with $r=0.88$ and $r=0.76$ (Table 3). These results indicate that soil organic carbon, nitrogen, and phosphorus have a crucial role to maintain grain nutrient composition of finger millet.

The variation in grain protein, calcium, and iron content at different altitudes might be due to the higher amount of SOC, N, and P in the soil because these components were found higher at upper altitudes. It justified the correlation coefficient (value of r) between grain nutrients and soil components (Table 3).

The grain protein increased along with increasing altitude in all landraces (Fig. 3) as well as soil components like phosphorus (Table 2), which might be due to the importance of P in the synthesis of protein, providing energy for the uptake and transfer of N in the grains of finger millet (Wekha et al. 2016). Similar results were also reported in cowpea (Magani and Kuchinda 2009), maize (Ali and Mohamad 2013), and lentils (Togay et al. 2008).

Comparatively low temperatures in higher elevation may stimulate seed protein synthesis and protein remobilization from vegetative organs to grains thereby increasing seed protein content (Diacono et al. 2012). However, at lower elevation daily maximum temperatures would reduce the duration of grain on genesis, result in a change in protein composition, and reduce the finger millet grain nutrients (Nadew 2018) and higher concentration of CO₂ gas including several physiological phenomenon in the lower elevation could be the reason of low grain nutrient (Dong et al. 2018; Myers et al. 2017) in comparison with higher altitudes.

The application of N, P, K fertilizers at different development stages significantly increased grain yield and nutrient composition in crops (Spratt 1974) but, in this study the yield and nutrients were determined under natural condition without external input of fertilizers in the field. So, higher nutrient content in grain of finger millet may be due to combined effect of climatic and adaphic factors.

Calcium and iron

The result shows that finger millet grains are comparatively richer in minerals and micronutrients than other main cereals (Vadivoo et al. 1998). Finger millet as the richest source of calcium (Kumar et al. 2018), containing about 0.34% as compared with 0.01–0.06% in most

other cereals (Kumar et al. 2018; Gupta et al. 2017). The analysis of nine varieties of millet revealed that Ca contents on grains varied from 0.05 to 0.32%. Gupta et al. (2011) reported 0.45% calcium in the grain of finger millet. However, the present study on ten local landraces of finger millet at three different altitudes showed higher Ca content, particularly high in the mid-hills of Central Nepal.

Finger millet also has the richest source of iron compare to other cereals viz rice, wheat and maize (Vijayakumari et al. 2003). According to Kumar et al. (2018), finger millet grain contains 0.32% iron, whereas, Admassu et al. (2009) reported grain iron of finger millet ranged from 0.05 to 0.54%. Singh and Srivastava (2006) reported that the iron content in 16 landraces of finger millet ranged between 0.36 and 0.54% with a mean value of 0.44%. Among 10 landraces of finger millet, Fe ranged from 0.36 to 0.49% with mean value 0.41% at 365 m elevation, while at 1040 m elevation, Fe ranged from 0.41 to 0.67% with mean value 0.53%, and at 1856 m elevation, Fe ranged from 0.66 to 0.82% with mean value 0.74%. These results indicate that iron content of finger millet grains is reasonably high at higher altitudes.

Soil chemical properties

The acidic nature of soil in higher altitudes as compared to lowlands is consistent with other findings in Nepal (Baumler and Zech 1994; Brown et al. 1999). The acidic nature of soil in the mid-hills was due to dominance of quartzite parent materials (Shrestha 2009).

The soil organic carbon percent was found highest (4.03%) in 1856 m elevation, which was similar with Phuyal (2013), followed by 1.88% and 1.91% in 1040 m and 365 m, respectively. The organic carbon of soil in the finger millet experiment site did not show that a specific pattern may be due to the farmers' role of using farmyard fertilizer in the fields.

Grain nutrient-soil chemicals-altitudes correlation

The altitudinal relationship between nutrients in finger millet grains and soil was analyzed through correlation coefficient. The grain protein and altitude showed a strong positive relation with $r=0.98$. This indicates that grain protein in finger millet increased with increasing altitude. Similarly, Ca and Fe in grain also showed a strong relationship between altitudes with r value 0.83 and 0.78, respectively (Table 3). The minerals (Ca and Fe) in finger millet grain increased with the altitude increase.

Sufficient amount of available phosphorus at higher altitudes probably enhanced the exchange reaction in soil by releasing ions in the microbial biomass that resulted in the greater availability of Ca also. The concentration of Ca in the soil solution helps to improve

Table 4 Correlation (r) between climatic variables and grain nutrient of finger millet at different altitudes in Central Nepal

	Alt	Temp	Rain	Protein	Ca	Fe
Alt	1.00					
Temp	-1.00	1.00				
Rain	-0.99	0.99	1.00			
protein	0.98	-0.98	-1.00	1.00		
Ca	0.83	-0.83	-0.76	0.72	1.00	
Fe	0.83	-0.83	-0.76	0.72	1.00	1.00

the architecture and energy provision through ATP, leading to the uptake of more quantities of calcium (Wafula et al. 2018; Sarwar et al. 2008) may be a cause of increased nutrient in grains of finger millet at higher altitudes.

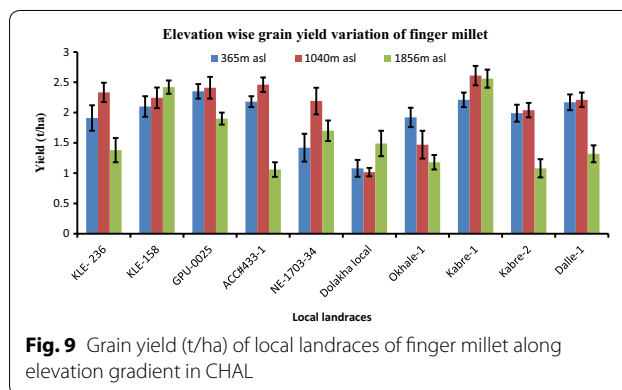
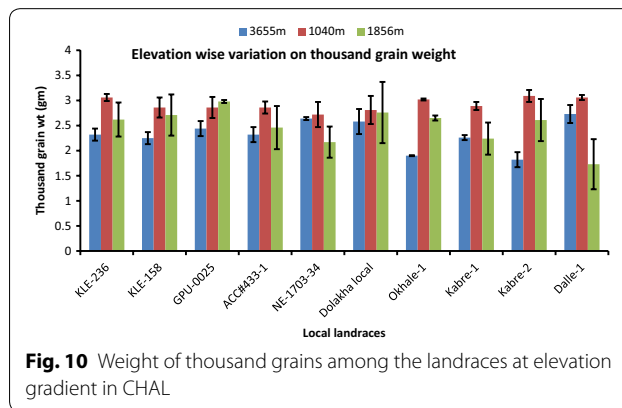
Adequate available P also increases the uptake of iron from soil through roots (Wafula et al. 2018). Greater amount available P in soil could be a factor of increased of iron in grains of finger millet at higher altitudes.

Nutrient, altitude, and climate correlation

The correlation between growing season temperatures and altitudes showed strong negative correlations with grain protein, Ca, and Fe, is $r = -0.98$, -0.83 , and -0.83 , respectively (Table 4). This implies that at higher elevations having at lower temperatures, finger millet protein, calcium, and iron content remain higher. This grain nutrient variation along different elevations may be due to the influence of genotype and environmental interactions in varying environment.

The yield and nutritional qualities of plants are influenced by numerous factors representing ecological conditions and management activities (Enoh et al. 2005). The altitudes and associated temperature, rainfall, slope and aspect of mountain as well as wind directions are important ecological factors that affect plants morphology, physiology and biochemistry of plants including nutrients compositions. Crops have obvious adaptation strategies by modifying their morphological and physiological characters (Royer et al. 2005; Qi et al. 2020). The average Ca increased by 0.21% and by 0.26% at higher altitude revealed increase of 0.11% and 0.21% of Fe due to the variation in soil characteristics and climate which determine the uptake of soil nutrients by plants (Begum et al. 2015).

Besides ecological and climatic factors, agronomic characteristics like yield, thousand grain weight can also influence the grain nutrients in finger millet. Grain yield and thousand grain weight of these 10 local

**Fig. 9** Grain yield (t/ha) of local landraces of finger millet along elevation gradient in CHAL**Fig. 10** Weight of thousand grains among the landraces at elevation gradient in CHAL

landraces at different elevations did not show any specific pattern, however some reflection of nutrients with the yield and thousand grain weight has been seen in this study (Figs. 9 and 10).

Conclusions

This study demonstrated the relationship among nutrients in finger millet (proteins, Ca and Fe), soil components (SOC, N, P and K), and altitudes, with respect to ambient climate. The grain nutrients (Nitrogen, Ca and Fe) of finger

millet at higher altitudes were found higher than lower altitudes. The nutrients (SOC, N, P, K) in soil also showed the same trend, increasing with increased altitude. The grain nutrients were strongly correlated with soil components, indicating that grain is richer in the soil having more nutrients. Similarly, there was a strong negative correlation between grain nutrients and temperature, which indicates that increasing temperature would decrease the nutrient quality of soil as well as quality of grain nutrient in finger millet in central Nepal.

Abbreviations

SOC: Soil organic carbon; N: Nitrogen; K: Potassium; P: Available phosphorus; Ca: Calcium; Fe: Iron; ATP: Adenosine triphosphate; ppm: Part per million; pH: Percentage of hydrogen; FRTC: Forests Research and Training Centre; CHAL: Chitwan Annapurna Landscape; UTSCR: Upper tropical to subtropical climatic region; LTRC: Lower tropical climatic region; TCR: Temperate climatic region; ATC: Agriculture Technology Centre.

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Authors' contributions

DRL: primary researcher, designed concept collected field data, gathering and processing of all data source, and prepared manuscript. MS, and PKJ supervised the works and edited the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets of this study will be available from corresponding authors on genuine request.

Ethics approval and consent to participate

Not applicable. We did research on crop plant and did not handle animals along protected areas. Thus no ethics protocol was required to be followed.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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