Nepalese Horticulture 19 : 95-102, 2025
ISSN : 2092-1122 | Print : 2542-2936 (Online)
DOI: 10.3126/nh.v19i1.86767

Research Article

OPEN ACCESS

Study of Physio-Chemical Properties of Local Potato Cultivars Grown in Different Districts of Gandaki Province

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Received on: 5 July, 2025 **Revised on:** 17 Oct, 2025 **Accepted on:** 27 Oct, 2025

Abstract

A study was conducted in 2024 across six districts of Gandaki Province to identify and evaluate the physio-chemical properties of different potato varieties. The objectives included mapping production areas, analyzing physical and chemical properties, and determining processing suitability via sensory evaluation. The physical traits assessed included tuber shape, weight, size, eye depth, flesh and skin color, and skin texture. Specific gravity, starch content, reducing sugar content, and dry matter content were the chemical parameters analyzed. This study revealed significant variations among the tested varieties. Tuber shapes ranged from oval to round, weighing 23.00 to 125.33 grams. Flesh colors varied from white to creamy white, and skin colors included white, purple, and red. All samples tested had smooth skin surfaces. Biochemical analysis revealed a reducing sugar concentration from 103.77 to 345.81 mg/100 ml, a dry matter content ranging from 12.40% to 29.94%, and a specific gravity between 1.08 and 1.11. The starch content ranged from 3.10% to 6.13%. Tharu Local, Mustang White Large, and Lahachok were found to be most suitable for chips and fries due to their high dry matter and starch content. Hemja and Jhakala were the most preferred in the organoleptic tests. This study suggests genetic profiling and legal registration of these varieties from the concerned authorities for preserving and improving the local potato cultivation.

Keywords: Chips, reducing sugar, sensory evaluation

Introduction:

Agriculture is a cornerstone of Nepal's economy, which contributes approximately 27% to Nepal's Gross Domestic Product (GDP). About 65% of Nepal's population is engaged in agriculture, making it the primary source of livelihood (Bhandari, 2024). But yields of many crops are very low compared to the neighboring countries and the world average. Potato is not an exception to this reality. Many farmers still use traditional and subsistence methods of farming with limited access to modern technology and inputs. Irrigation facilities are limited, with a large proportion of farmland depending on monsoon rains. Initiatives are underway to enhance agricultural research and extension services to share contemporary farming techniques and methods. But efforts are still low. As a result, agriculture faces numerous challenges, besides remaining a vital sector with significant potential for growth and development through targeted interventions and sustainable practices.

In Nepal's diverse food culture, certain crops play a vital role in ensuring both nutrition and sustenance for its people. Potato (*Solanum tuberosum* L.) is a stable food for people living in hills and mountains and one of the most important vegetable recipes of Nepalese cuisine (Upadhyay et. al., 2020). It occupies the first position in productivity among the food crops grown in Nepal, second position in total production, and fifth

position in area coverage (MoALD, 2021). The area and production of potato in Nepal is estimated at 198,256 ha and 3,410,829 t with a productivity of 17.20 t/ha, respectively (MoALD, 2021). In FY 2076/77, the potato was cultivated in 188,098 ha of land, which was increased by 6.17 % and 8.90 %, respectively, in FY 2077/78 and 2078/79. The productivity of potato is also increased over the last ten years. The productivity was 13.64 t/ha in 2012/13 and increased by 26.8 % (17.20 t/ha) in 2021/22 (Table 1).

Table 1: Area. Production and Yield of Potato for the last ten years (2012/13 to 2021/22)

Year	Area (ha)	Production (t)	Yield (t/ha)
2012/13	197,234	2,690,421	13.64
2013/14	205,725	2,817,512	13.70
2014/15	197,037	2,586,287	13.13
2015/16	199,971	2,805,582	14.03
2016/17	185,879	2,591,686	13.94
2017/18	195,268	3,088,000	15.81
2018/19	193,997	3,112,947	16.05
2019/20	188,098	3,131,830	16.65
2020/21	198,788	3,325,231	16.73
2021/22	198,256	3,410,829	17.20

Source: *Statistical Information on Nepalese Agriculture 2078/79 (2021/22)*

In Gandaki Province, the area, production, and productivity of potato is 20,263 ha, 340,633 t, and 16.81 t/ha, respectively, which is lower than that of Koshi, Madhesh, and Bagmati provinces (MoALD, 2021). Out of the total area under potato, around 10.22 % is in the Gandaki province (MoALD, 2021). This province ranks fifth in both area and production of potato and fourth in productivity among the seven provinces in Nepal t/ha (Table 2).

Table 2: Potato Production by Provinces, Fiscal year 2078/79 (2021/22)

Province	Area (ha)	Production (t)	Yield (t/ha)
Koshi	58,813	1,010,202	17.18
Madhesh	27,648	446,390	16.15
Bagmati	35,159	701,188	19.94
Gandaki	20,263	340,633	16.81
Lumbini	25,900	412,164	15.91
Karnali	13,919	237,598	17.07
Sudurpashchim	16,554	262,655	15.87
Total	198,256	3,410,829	17.20

Source: *Statistical Information on Nepalese Agriculture 2078/79 (2021/22)*

In 2020, potato production showed notable variation among countries, with average yields recorded at 20.82 t/ha in Bangladesh, 11.28 t/ha in Bhutan, 18.54 t/ha in China, 23.77 t/ha in India, 42.67 t/ha in the Netherlands, and 50.79 t/ha in the USA (FAOSTAT, 2021). Low productivity of potato in Nepal is associated with some common factors such as irrigation, fertilizer, varieties, diseases, insect pests, and other management practices. The most frequently mentioned yield-declining factors were low-yielding varieties, inadequate cultivation practices due to the soil-cultivar-climate complex, inadequate control measures for major diseases and insect pests, and insufficient soil fertility management practices (Upadhyay et al., 2020; NPRP, 2021). The reason behind the low productivity in Gandaki province is also the low-yielding potato varieties under cultivation for decades. The farmers seek alternate high-yielding varieties that suit their cropping systems. National Potato Research Program released eleven varieties, while it registered 5 varieties in the past (NPRP, 2020). These present varieties are not able to meet the requirements of farmers in the Gandaki province river basin conditions. These varieties could not be adopted widely in this region due to low productivity, late blight disease susceptibility, and poor keeping quality as well. Therefore, there is always a high demand for high-yielding varieties that are resistant

to diseases and insect pests and even perform in drought and dry conditions (Khatri and Luitel, 2014). Apart from the high-yielding varieties, area-specific varieties and quality planting material are the other most important factors for the successful cultivation of the crop.

Among the 11 districts in Gandaki province, Baglung has the highest area under potato cultivation, with production of 50,700 t, where the average yield is 16.25 t/ha, whereas Mustang has the lowest area of 320 ha with production of 5,792 t with the productivity of 18.10 t/ha, respectively. Manang and Gorkha districts have the highest yield, followed by Lamjung and Mustang (Table 3).

Table 3: Potato Production by Districts in Gandaki Province, Fiscal Year 2078/79 (2021/22)

Districts	Area (ha)	Production (t)	Yield (t/ha)
Manang	745	14,975	20.10
Mustang	320	5,792	18.10
Gorkha	2,550	51,255	20.10
Lamjung	1,975	38,503	19.49
Tanahun	1,856	29,882	16.10
Kaski	1,752	24,700	14.10
Parbat	1,340	18,790	14.02
Syangja	1,945	32,093	16.50
Myagdi	1,545	23,793	15.40
Baglung	3,120	50,700	16.25
Nawalparasi East	3,115	50,152	16.10

Source: *Statistical Information on Nepalese Agriculture 2078/79 (2021/22)*

Mountainous topography, associated with a cold climate at higher altitudes above sea level, makes it challenging to cultivate cereals and other food crops. Potato is the only crop that can be grown at an altitude of 3,000 m in a duration of 4-5 months. It yields good production, even at altitudes of up to 4,400 m (Pandey and Sarkar, 2005). Hence, potato serves as an important substitute for any other staple crop in this region. Apart from the high-yielding varieties, area-specific varieties and quality planting material are the other most important parts for the successful cultivation of the crop. Major pockets of potato cultivation in Gandaki province are Hemja, Dhorpatan, Salija, Dordi, Duwal, Tarakhola etc. Farmers rely on seed tubers that have been propagated for over 25 years. Farmers receive a good price for their potato tubers after harvesting, as the market is dominated by popular brands such as Mustang potato, Tarakhola potato, Dhorpapan potato, Hemja potato, and Tharu potato, among others (Karki et al., 2023).

The Tharu community in Nawalpur cultivates the special potato, smaller in size with good taste, suited for culinary purposes. Besides the culinary purpose, the potatoes produced in Gandaki province can also be further processed into different forms, such as chips and fries. Value chain development in potato and its linkages to the regional and global value chain as a source of better income for farmers of Gandaki Province is a must. Processing potatoes into chips, fries, and other value-added products can open up new market opportunities and increase farmer incomes. Small-scale processing units and cooperatives must be encouraged to capitalize on this potential. The study aims to evaluate the different physical properties of local potato varieties of Gandaki province, evaluate their biochemical properties, and find out the appropriate variety suitable for processing through sensory evaluation.

Materials and Methods:

A field visit was conducted in 2024 in 11 districts of Gandaki Province. Based on the information collected from Agriculture Knowledge Center, Agriculture Development Section at the Local levels, and secondary data from published reports, the location-specific potato varieties being grown by farmers were identified and listed with their names. Among the 11 districts in Gandaki province, samples were collected from Mustang, Manang, Myagdi, Parbat, Kaski, and Nawalpur. The name for the collected varieties was given based on the collection area. The collected sample tubers were sent to horticulture laboratory of College of Natural Resource Management, Puranchaur, Kaski and evaluation of almost all physical properties like tuber shape, tuber size, eye depth, color of the flesh and tuber skin color, and sensory evaluation like chips color, taste, crispness and overall acceptance was performed, whereas the evaluation of bio-chemical properties like dry matter content, specific gravity, starch and reducing sugar content was done at National Food Research Program, Khumaltar, Lalitpur. The tuber shape, colour of the flesh, tuber skin color, and tuber surface were visually observed. Tuber size and eye depth

were measured with a vernier caliper. Dry matter content was measured by randomly selecting tubers, chopping and mixing them into small pieces, and then drying a 100-gram sample in a hot air oven; initially at 80°C for six hours, followed by 65°C until a constant weight was achieved (Kumar et al., 2006). The specific gravity was determined by weighing randomly selected ten tubers on a Kern electric balance in air and water. Quantification of reducing sugars was done by the 3,5-dinitrosalicylic acid (DNS) method (Miller, 1959). Hedonic ranking for chips color, taste, and overall acceptance was made on a 1-9 scale, whereas crispness ranking was done on a 1-3 hedonic scale. The collected quantitative and qualitative data were coded, entered, and edited with the help of Microsoft Excel, and analysis was done with the help of Excel in percentages, means, and averages.

Results:

Physical Properties

The different physical properties of potato include shape, weight, length, width of the tuber, eye depth, flesh color, skin color, and skin surface. Based on the physical properties of potato varieties grown in different districts of Gandaki province, the following characters are observed as in Table 4.

***Weight**:* The weight of the potatoes ranged from 23.00 g (Tharu) to 125.33 g (Jaljala Rato). This wide range indicates diverse growth conditions and genetic variations among the potato varieties. Heavier potatoes, such as Jaljala Rato, might be preferred for bulk processing, while lighter ones, like Tharu, could be suitable for niche markets.

***Length and Width**:* Jaljala Rato also had the longest (119.32 mm) and widest (50.78 mm) dimensions, suggesting it may be particularly suited for uses where larger potato sizes are desirable, such as baking or large-scale culinary preparations. Conversely, smaller dimensions seen in Tharu and Galkot Bhatti might cater to different consumer preferences or specific culinary uses.

***Eye Depth**:* Eye depth ranged from 0.70 mm (Jhakalaka Falebas) to 2.20 mm (Tharu). Potatoes with shallower eyes are typically easier to peel and process, which can be a significant advantage in both commercial and domestic contexts.

***Flesh and Skin Color**:* The flesh color varied between white and creamy white, and skin colors included white, purple, creamy white, and red. Varieties like Hemja and Myagdi Purple with unique purple skin can be marketed for their aesthetic appeal and potential health benefits due to higher anthocyanin content.

***Shape**:* The observed shapes (oval, elongated, oblong, round) influence the suitability of potatoes for various

Table 4. Study of physical properties of potato varieties grown in different districts of Gandaki province

S.N.	Location/Local Name	Shape	Weight (g)	Length (mm)	Width (mm)	Eye Depth (mm)	Flesh Color	Skin Surface	Skin Color
1	Lahachock	Oval	95.00±1.65	75.14±1.50	46.71±1.16	1.20±0.14	White	Smooth	White
2	Hemja	Elongated	101.33±2.04	96.73±1.50	49.09±0.37	0.96±0.16	White	Smooth	Purple
3	Myagdi Purple	Elongated	70.33±1.37	85.44±1.06	42.32±1.31	0.93±0.34	Creamy White	Smooth	Purple
4	Myagdi White	Oblong	69.33±2.33	68.85±2.06	43.82±1.31	0.72±0.34	Creamy White	Smooth	Creamy White
5	Mustang Seto Thulo	Oval	95.00±1.77	78.73±2.69	49.06±1.10	0.76±0.24	Creamy White	Smooth	White
6	Mustang Sano	Oval	44.67±2.78	56.83±2.54	39.43±0.45	0.76±0.24	White	Smooth	White
7	Tarakhola	Oblong	59.00±1.98	61.29±2.66	45.09±2.99	0.72±0.25	White	Smooth	White
8	Galkot Bhatti	Round	31.33±2.03	44.93±2.90	36.10±2.94	0.76±0.19	Creamy White	Smooth	White
9	Jhakalaka, Falebas	Oblong	63.67±0.59	67.52±2.91	41.67±1.17	0.70±0.17	White	Smooth	White
10	Jaljala Seto	Round	46.33±0.33	55.93±2.36	38.00±2.00	1.14±0.04	Creamy White	Smooth	White
11	Jaljala Rato	Elongated	125.33±2.46	119.32±1.24	50.78±2.75	1.02±0.31	Creamy White	Smooth	Red
12	Tharu	Round	23.00±1.53	36.93±1.43	32.57±2.23	2.20±0.27	Creamy White	Smooth	White

***Note:** Values are presented as mean ± standard error of the mean (SEM).*

culinary applications. Elongated shapes like Hemja and Myagdi Purple may be ideal for fries, while round shapes like Tharu and Galkot Bhatti may be better for boiling or roasting.

***Skin Surface**:* All samples had a smooth skin surface, which is generally preferred for ease of cleaning and processing.

Bio-chemical Properties

The processing of potatoes into chips and fries depends heavily on their biochemical properties. The data collected from various potato varieties grown in different districts of Gandaki province provides insight into these properties, specifically specific gravity, moisture content, dry matter content, reducing sugar content, and starch content (Table 5). These properties are crucial for determining the suitability of potatoes for processing into chips and fries.

Specific Gravity: Specific gravity is an indicator of the dry matter content in potatoes. Higher specific gravity values are generally associated with better frying quality. Potatoes with a higher specific gravity absorb less oil, producing crisper fries and chips. According to the data, the specific gravity of the potato varieties ranges from 1.08 to 1.11. Varieties such as those from Lahachock, Mustang Seto Thulo, and Jaljala Seto have the highest specific gravity (1.11), indicating they are potentially the most suitable for processing into chips and fries.

Moisture Content: Moisture content is inversely related to the dry matter content. Lower moisture content in potatoes is preferable for frying as it results in less oil absorption and a crispier texture. The moisture content of the potato varieties varies significantly, from as low as 64.32% in the Tharu variety to as high as 77.37% in the Hemja variety. The Tharu variety, with the lowest moisture content, is particularly promising for chip and fry production.

Dry Matter Content: Dry matter content is crucial for determining the yield and texture of the final fried product. Potatoes with higher dry matter content tend to produce higher yields of fries and chips with a desirable texture. The dry matter content ranges from 22.63% (Hemja) to 35.68% (Tharu). Again, the Tharu variety stands out with the highest dry matter content, making it a top candidate for processing.

Reducing Sugar Content: Reducing sugars in potatoes can cause browning during frying due to the Maillard reaction, which affects the color and taste of the chips and fries. Ideally, potatoes used for frying should have low reducing sugar content. The varieties show a wide range in reducing sugar content, from 103.77 mg/100ml (Jaljala Rato) to 345.81 mg/100ml (Jhakalaka Falebas). Varieties with lower reducing sugar content, such as Jaljala Rato, are better suited for frying to avoid excessive browning.

Starch Content: Higher starch content contributes to a fluffier texture in fries and a crisper texture in chips. The starch content of the varieties varies from 3.10% (Jaljala Seto) to 6.13% (Mustang Seto Thulo). Mustang Seto Thulo, with the highest starch content, is highly suitable for processing due to its potential for producing superior texture in fried products.

Sensory evaluation/Organoleptic taste

The sensory evaluation table provides insight into the organoleptic qualities of the potatoes, which are crucial for consumer acceptance (Table 6).

***Color**:* Most varieties were pale yellow to very pale

Table 5. Study of biochemical properties of different potato varieties grown in different districts of Gandaki province

S.N.	Location/Local Name	Sp. Gravity	Moisture %	Dry Matter %	Reducing Sugar Content (mg/100ml)	Starch Content (%)
1	Lahachock	1.11±0.01	73.42±0.05	26.58±0.05	157.50±1.15	3.92±0.13
2	Hemja	1.08±0.00	77.37±0.66	22.63±0.66	132.47±1.25	3.63±0.14
3	Myagdi Purple	1.09±0.00	76.93±0.52	23.07±0.52	152.56±1.37	4.68±0.16
4	Myagdi White	1.10±0.00	76.36±0.13	23.64±0.13	134.08±1.38	4.41±0.12
5	Mustang Seto Thulo	1.11±0.00	67.54±0.52	32.46±0.52	158.78±0.91	6.13±0.20
6	Mustang Sano	1.09±0.01	74.27±0.49	25.73±0.49	116.35±0.88	4.62±0.13
7	Tarakhola	1.09±0.02	72.09±0.20	27.91±0.20	229.53±1.45	3.74±0.15
8	Galkot Bhatti	1.09±0.02	69.97±0.98	30.03±0.98	132.45±1.56	5.39±0.16
9	Jhakalaka, Falebas	1.10±0.01	68.64±0.14	31.36±0.14	345.81±1.91	5.80±0.17
10	Jaljala Seto	1.11±0.01	76.83±0.67	23.17±0.67	126.02±0.58	3.10±0.17
11	Jaljala Rato	1.09±0.00	75.88±0.39	24.12±0.39	103.77±1.92	4.72±0.19
12	Tharu	1.11±0.02	64.32±0.03	35.68±0.03	201.23±0.91	5.31±0.18

Note: *Values are presented as mean ± standard error of the mean (SEM).*

Table 6. Study of sensory evaluation/organoleptic taste of potato varieties grown in different districts of Gandaki province of Potato

S.N.	Location/Local Name	Color	Taste	Crispness	Overall Acceptability
1	Lahachock	Pale Yellow	Good to very good	Too Crispy	Like very much
2	Hemja	Very pale yellow	Very good	Too Crispy	Like extremely
3	Myagdi Purple	Pale yellow	Good to very good	Too Crispy	Like very much
4	Myagdi White	Brown	Good	Too Crispy	Like slightly
5	Mustang Thulo	Pale cream till white	Good	Ideal	Like Moderately
6	Mustang Sano	Pale yellow	Moderate to good	Ideal	Like Slightly
7	Tarakhola	Cream	Good to very good	Too Crispy	Like Slightly
8	Galkot	Pale yellow	Good	Too Crispy	Like Slightly
9	Jhakalaka	Pale cream till white	Very good	Too Crispy	Like moderately
10	Jaljala White	Brown	Good to very good	Too Crispy	Like moderately
11	Jaljala Red	Very pale yellow	Good	Ideal	Like very much
12	Tharu	Brown	Good	Ideal	Like slightly

yellow, with some exceptions like Myagdi White and Jaljala White, which were brown. The color can influence consumer perceptions. Pale and bright colors are often associated with the freshness of the tuber and quality.

Taste*:* Varieties like Hemja and Jhakalaka received very good ratings, indicating strong consumer preference for these tastes. Moderate to good ratings were given to varieties like Mustang Sano, which might suggest room for improvement or niche market appeal.

Crispness*:* Many varieties were noted as "Too Crispy," which could be beneficial or detrimental depending on the intended use (e.g., crispy for chips but possibly less desirable for mashed potatoes). Varieties like Mustang Thulo and Tharu, described as "Ideal," could be more versatile.

Overall Acceptability: Hemja received the highest level of acceptance ("Like extremely"), indicating strong market potential. Varieties like Jaljala Red and Lahachock, which were also highly liked, suggest they could perform well in consumer markets. Conversely, varieties like Myagdi White and Mustang Sano, which were liked slightly, might require marketing efforts to highlight their unique qualities or improvements in cultivation practices.

Discussion:

Length, width, and thickness are significant factors in potato tubers as they influence their suitability for processing into products like French fries and chips (Evelyne et. al., 2021). Elongated tubers are ideal for producing French fries, whereas those with a greater width are favored for making chips. Tubers measuring 50 mm or more in length are optimal for French fry production (Nain et al., 2019). For processing purposes, long and oval-shaped tubers are preferred (Wayumba et al., 2019). The number and depth of eyes are primarily determined by the variety (Nain et al., 2019). A deeper eye depth can negatively impact efficiency in peeling and trimming during processing (Evelyne et. al., 2021).

Based on the analysis of the biochemical properties, the Tharu, Mustang Seto Thulo, and Lahachock varieties emerge as the most suitable candidates for processing into chips and fries. Tharu, with its high dry matter and low moisture content, is particularly advantageous for producing high-yield, high-quality fried products. Mustang Seto Thulo, with its high specific gravity and starch content, is also excellent for achieving the desired texture in chips and fries. Lahachock, with its high specific gravity, further complements the selection for processing purposes. These varieties can be prioritized for cultivation and processing to optimize the production of chips and fries in the Gandaki province. The specific gravity of potatoes is widely regarded as a key indicator of their quality, as it correlates positively with the levels of starch, total solids, and dry matter (Mohammed, 2016). A higher specific gravity is preferred for the production of dehydrated and fried products because it leads to improved product yield, reduced oil absorption, decreased energy usage during processing, enhanced flavor and texture, and generally superior quality of fried items (Wayumba et al., 2019). The amount of simple sugars present is an important quality factor when choosing tubers for processing. When potatoes undergo high-temperature cooking methods like frying or baking, their reducing sugars react with free amino acids, especially asparagine, in a non-enzymatic process known as the Maillard reaction (Campos and Ortiz, 2020). This reaction produces a compound called acrylamide, which is considered a potential carcinogen and has raised worldwide food safety issues regarding products such as French fries and chips (Campos and

Ortiz, 2020). Moreover, a high level of reducing sugars results in the creation of dark, bitter fries and chips, which are undesirable (Clasen et al., 2016).

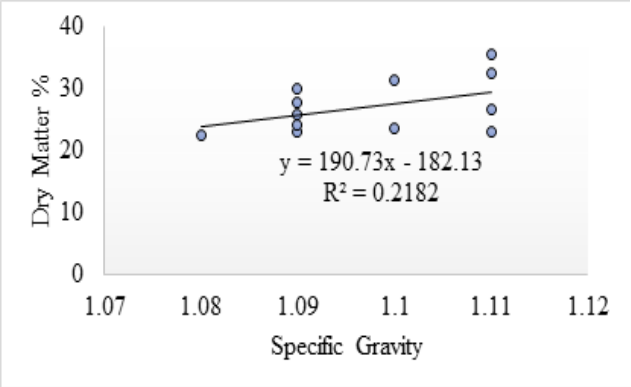

Figure 1: Correlation between specific gravity and dry matter content of potato tubers

Conclusion:

The comprehensive analysis of different potato varieties collected from Gandaki Province reveals substantial diversity in both physical and biochemical properties. This diversity indicates the potential for different uses in culinary and industrial applications, depending on the specific characteristics of each variety. Varieties like Jaljala Rato, with its larger size and higher weight, are well-suited for bulk processing and baking, while smaller varieties like Tharu might cater to niche markets. The variations in specific gravity, moisture content, and dry matter are particularly important for processing industries, influencing factors such as fry quality and storability. Potatoes with higher dry matter content and appropriate reducing sugar levels are preferable for producing high-quality fried products. The unique colors and shapes also offer marketing opportunities, appealing to consumers seeking aesthetic and health benefits associated with diverse potato varieties. Overall, this study highlights the importance of promoting and cultivating a wide range of potato varieties to meet diverse market demands and support sustainable agricultural practices in Gandaki Province. Future research and development efforts should focus on enhancing the yield and quality of these varieties while ensuring they meet the specific needs of both local and international markets.

Acknowledgement:

The authors would like to acknowledge the Directorate of Agriculture Development, Gandaki Province, Pokhara, for providing a research grant to conduct this study.

Declaration of conflict of interest and ethical approval:

The authors declare no conflicts of interest regarding the publication of the manuscript.

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