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Research Article

Performance of drought tolerant rice varieties in different altitudes at Duradada, Lamjung, Nepal

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ABSTRACT

To evaluate high yielding drought tolerant rice varieties in different altitudes, a field experiment was carried out at Duradanda, Lamjung, Nepal during rainy season of 2016 under rainfed condition. The experiment was laid out in a factorial randomized block design with two replications. The treatments comprised of six different rice varieties viz. Sukhadhan-1, Sukhadhan-2, Sukhadhan-3, Sukhadhan-4, Sukhadhan-5 and Sukhadhan-6 and four altitudes viz. 1000, 1200, 1400 and 1600 masl. The results revealed that rice variety Sukhadhan-2 produced the highest grain yield (2.93 t/ha) followed by Sukhadhan-5 (2.92 t/ha) and Sukhadhan-3 (2.82 t/ha). The highest grain yield of Sukhadhan-2 was due to higher number of effective tillers/m^2 (228), higher number of grains/panicle (83), higher panicle length (21.79 cm) and low sterility percentage (27.91%) as compared to other varieties. Regarding to altitudes, the highest grain yield (3.34 t/ha) was obtained in lower altitude (1000 masl) followed by 1200 masl (2.79 t/ha), 1400 masl (2.68 t/ha and 1600 masl (1.85 t/ha). The lower yield in higher altitude was due to higher sterility percentage, less number of effective tillers per unit area and less number of effective grains per panicle. It seems that the performance of these varieties was good up to 1400 masl.

Keywords: Biological yield, elevation, stress tolerance, Sukhadhan, sterility

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INTRODUCTION

Rice is one of the most important cereal crops in the world and is the foremost staple food of Asian people which provides 35-60% of the dietary calories for about nearly three billion people (Liu *et al.*, 2010, Kandel and Shrestha, 2018). The developing countries account for about 95% of the total rice production where China and India alone produced nearly half of the world output. Katsura *et al.* (2008) reported that the altitude of planting fields of rice is a very important environmental factor that affect on yield and quality of rice. In high altitude areas, the atmospheric air density decreases, air temperature gradually decreases, solar radiation intensity increases and ultraviolet rays intensity becomes strong that affects on yield and quality of rice.

In Nepal, it is a staple food crop and fulfill more than 50% of the calorie requirement of Nepalese people (Gautam *et al.*, 2018; Lamsal *et al.*, 2018; Kharel *et al.*, 2018: Gadal *et al.*, 2019) grown from Terai to high hills areas. To feed ever increasing population, rice production in Nepal has to be increased over 6.0 million tons by 2020 to meet the growing demand of ever increasing population (Kharel et al., 2018). The production and productivity of rice has not geared up as much as required with traditional system of cultivation despite a lot efforts are being made. Farmers' rainfed rice fields along toposequences are characterized by a high degree of heterogeneity in topography and soil conditions, so that rice crop performance varies from year to year and from location to location. The climate of Nepal differ from cool summer to severe winter which serves as micro museum of the world (Paudel, 2009).The area, production and productivity of rice in Nepal is 1.47 million ha, 5.15million tons with 3.50 tons/ha, respectively, whereas the area, production and productivity of rice in Lamjung district was recorded to be 14,059 ha, 37,772 tons and 2.7 t/ha (Bhandari *et al.*, 2019). Productivity of rice was very low as compared to developed nation. The low average yields indicate that there is a considerable yield gap between attainable yields and actual mean yields in farmers' fields in many production situations. Many biotic (Insect, pest etc) and abiotic stress (drought, flood etc) are responsible for lowering the productivity of rice. The productivity of the rainfed lowland rice area is low compared to the irrigated lowland because of the absence of a reliable water source, long drought spells and poor soil condition which limits or reduces grain yields. Small to medium topographic differences may cause considerable variability in water availability and also the variability of soil factors like texture, soil fertility status and soil toxicities. The problem of food insecurity and poverty, the agriculture research institutions of Nepal have provided several need-based output-oriented research findings but they all are not practiced in the farmers' fields (Joshy and Pandey, 2005).

Drought is one of the major abiotic stress responsible for lowering the rice area, production as well as productivity. It is projected that 15-20 million hectares of irrigated rice may experience some degree of water scarcity by 2025 (Bouman *et al.*, 2001). Around 23 million hectares of rainfed rice growing area are estimated to be drought prone in south and Southeast Asia (Pandey *et al.*, 2007). Drought is a condition of any areas where the precipitation is below average, resulting prolonged shortages of water supply, sufficient to cause loss of yield. Drought is a single most important factor to increase and stabilize production of rice under rainfed condition in mid mills of Nepal (Adhikari, 2009). The proper

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and appropriate phenotyping plays an increasingly important role in the selection of drought-resistant genotype (Shrestha, 2019)

There are more than seventy varieties of rice released by variety releasing subcommittee of Nepal upto now. These varieties are released based on different agro-ecological conditions of Nepal. Altitude is the important factor affecting the rice yield and quality reported by (Khush and Peng. 1996; Katsura *et al.,* 2008). There are some drought tolerant rice varieties (DTR) such as Sukhadhan-1, Sukhadhan-2 and Sukhadhan-3 released in 2011 and Sukhadhan-4, Sukhadhan-5 and Sukhadhan-6 were released in 2014. These were released for targeting rainfed low land condition from terai to lower hills upto 1000 masl. These six varieties are popular from terai to lower foot hills of Nepal (Tripathi *et al.,* 2012). Anon (2008) reported that rice cultivating area of Kashmit region with an altitude of 1300-2000 belonging to mid altitude region whereas the higher altitude regions have an altitude greater than 2,000 masl. There are limited research conducted in mid to higher altitude areas to find out the effects of altitude on rice yield and quality. The performance of newly released DTR varieties and their adoption in higher elevation above 1000 masl is utmost necessary at this situation. So, an experiment was designed to evaluate the performance of newly released six drought tolerance rice varieties in different altitude at Durananda, Lamjung Nepal during rainy season 2016.

MATERIALS AND METHODS

Research site

The experiment was carried out at Duradada Lamjung, Nepal from an altitude of 1000 m (Archaleni) to 1600 masl (Turlungkot) during rainy season of 2016. The site is situated about 20 km west from Beshisahar, the head quarter of Lamjung district. Duradanda is considered to be the place of origin of the 'Dura' tribe. Duradanda is under Sundarbazar municipality covered an area of 72.05 km^2 remains in southern slope. Bhramin, Kshetri and Dura are dominated cast. The altitude of the research site varies from 800 to 2000 m and the latitude variation of this village is 28º 7’ to 28º 10’ north and longitudinal variation is 84º24’ to 84º 28’. Study village lies in the sub-tropical climatic belt of Nepal. The area has sub-humid type of weather condition with cold winter, hot summer and distinct rainy season. The minimum temperature (6-10ºC) never goes to freezing point even during December-January (the coldest months) and the maximum winter temperature rises up to 25^0C. The hottest months of the year are April, May and June, when the maximum temperature rises up to 39^0C (District Profile of Lamjung, 2006).

Experimental details

The six rice varieties (Sukhadhan-1, Sukhadhan-2, Sukhadhan-3, Sukhadhan-4, Sukhadhan-5, Sukhadhan-6) and four different altitudes. (1000 masl, 1200 masl,1400 masl and 1600 masl) were evaluated in randomized complete block design with two replications. These rice varieties were received from National Rice Research Program, Hardinath, Dhanusha, Nepal. The experiments were carried out in farmers’ fields. Seedling preparation, transplanting, intercultural operations, water management and fertilizer management was done as farmers’ practice. The researchers have involved for taking data of phenological, growth, yield and yield attributing characters. Data tabulation, analysis and means variation was done by using software MS Excel 2010 and MSTATC version 1.3.The treatment means were compared by

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the Least Significant Difference (LSD) test at 5% level of significance (Gomez & Gomez, 1984; Shrestha, 2019; Devkota *et al*., 2019; Pandey et al., 2019; Kandel & Shrestha, 2019).

RESULTS

Phenological character

Maturity day was found statistically significant among the tested varieties (Table 1). The early maturity was found in Sukhadhan-2 (132 days) followed by Sukhadhan-1 and Sukhadhan-6 (133 days each) whereas about 4-5 days late maturity (137 days) was found in Sukhadhan-5. Regarding to the altitudinal effect, early maturity was found in 1000 masl (129 days) followed by 1200 masl (133 days) and 1400 masl (136 days) while late maturity was found in 1600 masl (138 days).

Growth characters

Plant height and panicle length were found statistically highly significant among the tested varieties in the experiment. The tallest plant height was measured in Skhadhan-5 (103.4 cm) followed by Sukhadhan-2 (103.2 cm) and Sukhadhan-1 (103.6 cm) which were statistically at par, while the lowest plant height was found in Sukhadhan-6 (82.89 cm). The plant height in different altitudes showed that the lowest altitude (1000 m) produced taller plants (137 cm) compared to higher altitudes 1600 masl (130 cm). Similarly in case of panicle length, the longest panicle was measured in Sukhadhan-1 (20.85cm) followed by Sukhadhan-3 (20.72 cm) and Sukhadhan-5 (20.13 cm) whereas the minimum panicle length was found in Sukhadhan-6 (19.82 cm). In case of altitudinal effect, the lower altitude (1000 m) produced longest panicle (20.80 cm) followed by 1400 m (20.30 cm) and 1200 masl (20.26 cm) whereas the shortest panicle was in 1600masl (19.07cm) (Table 1).

Effective tillers per m^2

Statistically highly significance differences found effective tillers per unit area in different tested varieties (Table 1). The highest number of effective tillers were counted in Sukhadhan-2 (238) followed by Sukhadhan-5 (233) and Sukhadhan-3 (231) where as the lowest number of effective tillers per m2 was measured in Sukhadhan-1 (220 tillers). Similarly, in case of different altitude, the highest number of effective tillers per m^2 were found in 1000 m altitude (251 tillers) followed by 1200m (230 tillers) and 1400 m (224 tillers) where as the minimum tillers (192 tillers) were found in higher altitude (1600 m).

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Table 1 Effects of altitudes and varieties on phonological, growth and yield attributing characters of rice at Duradada Lamjung during rainy season, 2016

Treatment combination		Maturity days	Plant height (cm)	Panicle length (cm)	Effective tillers /m^2
1. Variety (A)	V_1: Sukhadhan-1	133^{b}	102.6^{a}	20.85^{b}	220^{b}
	V_2: Sukhadhan-2	132^{b}	103.2^{a}	19.83^{abc}	238^{a}
	V_3: Sukhadhan-3	135^{a}	86.76^{c}	20.72^{ab}	231^{a}
	V_4: Sukhadhan-4	133^{b}	95.33^{b}	19.30^{c}	221^{b}
	V_5: Sukhadhan-5	137^{a}	103.4^{a}	20.13^{abc}	233^{a}
	V_6: Sukhadhan-6	133^{b}	82.89^{c}	19.82^{bc}	203^{c}
F test		**	**	*	**
LSD (0.05)		2.17	6	1.03	7
2. Altitude (B)	A_1: 1000	129^{d}	137^{d}	20.80^{a}	251^{a}
	A_2: 1200	133^{c}	134^{c}	20.26^{ab}	230^{b}
	A_3: 1400	136^{b}	132^{b}	20.30^{ab}	224^{c}
	A_4: 1600	138^{a}	130^{a}	19.07^{b}	192^{d}
F test		**	**	*	**
LSD(0.05)		1.58	0.54	1.49	5.88
Interaction (A x B)		*	NS	**	NS
CV (%)		3.9	0.6	10	3.9

**Indicates significant difference among the tested genotypes (where, p is> 0.01 to <0.05). **indicates the highly significant difference among the tested genotypes (where, p is <0.05). ns=non-significant difference among the tested genotypes (where, p > 0.05).Means within the column followed by same letters are not different at 5% level of significance*

Effective grains per panicle

The highest numbers of effective grains per panicle was found in Sukhadhan-2 (83 grains) followed by Sukhadhan-5 (80 grains and Sukhadhan-3 (76 grains) (Table 2). The lowest grains per panicle were found in Sukhadhan-6 (68 grains) Similarly, in case of altitudinal effect, the highest number of effective grains per panicle were found in 1000 masl (87 grains) and lowest was observed in 1600 masl (65 grains).

Sterility (%)

Statistically significant difference were found on sterility percentage among the tested genotypes of rice (Table 2).The highest sterility percentage was found in Sukhadhan-6 (31.93 %) followed by Sukhadhan-3 (30.97%), whereas lowest sterility percentage was found in Sukhadhan-2 (27.91%). The effect of different altitudes on sterility showed that the highest sterility was found in 1600 masl (39.07%) followed by 1400 masl (32.11%) and 1200 masl (27.2%). The lowest percentage of sterility was observed in 1000 masl (21.18%). In high altitude, less grain settings may occurs because of cold injury and high mortality percentage of pollen grains.

Grain yield

Grain yield were found to be statistically significant among the tested genotypes (Table 2). Maximum grain yield was obtained from Sukkhadhan-2 (2.93 t/ha) and Sukhadhan-5 (2.92 t/ha) followed by Sukhadhan-3 (2.82 t/ha). Statistically, Sukhadhan-1 and Sukhadhan-4 are at par having grain yield 2.92 and 2.52 t/ha respectively. Regarding to effect of altitude on grain yield, statistically significant differences were found in different altitudes. The highest grain

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yield was obtained from lower altitude (1000 masl) (3.34 t/ha) followed by 1200 masl (2.79 t/ ha) and (1400 masl) (2.68 t/ha) whereas the lowest grain yield was obtained in higher altitude (1600 masl) (1.85 t/ha). The highest grain yield in lower altitude might be due to high photosynthetic efficiency, less pollen mortality and good grain setting.

Straw yield

Straw yield were found to be statistically significant among the tested genotypes**.** The highest straw yield was obtained from sukhadhan-2 (4.14 t/ha) followed by Sukhadhan-3 (3.13 t/ha) and Sukhadhan-5 (4.12 t/ha) whereas minimum straw yield was obtained from Sukhadhan-6 (3.99 t/ha).

Harvest Index

Harvest index were found to be statistically significant among the tested genotypes (Table 2).

Table 2 Effects of altitudes and varieties on yield attributing characters of rice at Duradada Lamjung during rainy season 2016

Treatment combination	Effective grains/ panicle	Sterility%	Grain yield t/ha	Straw yield (t/ha)	Harvest index
Variety (V)					
Sukhadhan-1	75^{c}	29.19^{c}	2.52^{b}	4.04^{b}	37.84^{b}
Sukhadhan-2	83^{a}	27.91^{d}	2.93^{a}	4.14^{a}	41.22^{a}
Sukhadhan-3	76^{c}	30.97^{ab}	2.82^{a}	4.13^{a}	40.27^{a}
Sukhadhan-4	76^{c}	30.15^{bc}	2.59^{b}	4.05^{b}	38.58^{b}
Sukhadhan-5	80^{b}	29.20^{c}	2.92^{a}	4.12^{a}	41.09^{a}
Sukhadhan-6	68^{d}	31.93^{a}	2.22^{c}	3.99^{c}	34.73^{c}
F test	**	**	**	**	**
LSD(0.05)	2.8	0.99	0.15	0.03	1.29
Altitude, A (m)					
1000	87^{a}	21.18^{d}	3.34^{a}	4.41^{a}	43.05^{a}
1200	81^{b}	27.20^{c}	2.79^{b}	4.24^{b}	40.89^{b}
1400	72^{c}	32.11^{b}	2.68^{b}	3.84^{c}	39.67^{c}
1600	65^{d}	39.07^{a}	1.85^{c}	3.82^{c}	32.20^{d}
F test	**	**	**	**	**
LSD(0.05)	2.28	0.81	0.12	0.03	1.06
Interaction (V x A)	**	**	**	NS	**
CV (%)	4.5	4	7	1.1	4.1

***indicates the highly significant difference among the tested genotypes (where, p is <0.05).Means within the column followed by same letters are not different at 5% level of significance*

The highest harvest index was found in Sukhadhan-2 (41.22%) followed by Sukhadhan-5 (41.09%) and Sukhadhan-3 (40.27%) whereas the lowest harvest index was found in Sukhadhan- 6 (34.73%). Regarding to effect of altitudes on harvest index, the maximum harvest index was found in lower altitude (1000 masl) (43.05%) followed by 1200 masl (40.89%) and 1400 (39.67%) whereas the minimum harvest index was found in 1600 masl (32.20%). The lowest harvest index in higher altitude might be due to less production of economic yield in that area.

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Interaction

Statistically significance differences found between four level altitudes and six different DTR varieties tested in the experiment (Table 3). The maximum grain yield of all varieties is found in lower altitude (1000 m) followed by 1200 m, 1400 m and 1600 m above mean sea level. Among different varieties, the performance of Sukhadhan-2 was fond better in 1000 masl (5.03 t/ha) followed by Skhadhan-1 (4.79 t/ha) while the minimum grain yield was obtained Skhadhan-4 (3.46 t/ha).

Table 3. Interaction effect between altitude and variety on grain yield (t/ha) of rice in the experiment during 2016

Parameters	Rice vvarieties					
Altitudes (m)	Sukhadhan-1	Sukhadhan-2	Sukhadhan-3	Sukhadhan-4	Sukhadhan-5	Sukhadhan-6
1000	4.79	5.03	4.40	3.46	4.19	4.17
1200	2.81	3.79	4.72	3.49	3.65	3.99
1400	2.62	2.79	3.56	2.94	3.24	2.56
1600	2.11	2.37	1.36	1.47	1.75	1.36
Mean	3.08	3.495	3.51	2.84	3.2075	3.02

The grain yield of all varieties seems to be decreasing in trend when the altitudes are increasing. Among different varieties in higher altitude (1600 masl), the performance of Sukhadhan-2 was found better (2.37 t/ha) followed by Skhadhan-1 (2.11 t/ha) and Sukhadhan-5, while minimum yield was obtained from Skhadhan-3 and Sukhadhan-6 (1.36 t/ha each).

DISCUSSION

Plant height showed that most of the tested varieties were semi-dwarf type and is positively responsive to inputs like fertilizers and irrigation. According to Reddy and Reddy (2002), the ideal rice plant should be of medium height. Adhikari (2009) reported that varieties with medium duration and small to medium height with a big flag leaf and high chlorophyll content can accumulate more dry matter than others. All the tested varieties were modern types and the plant architecture is ideal type and can expect to get maximum yield. Wang *et al.* (1984) reported that the height of rice plants will shorten with the increase of the altitude; the leaves of the main stalk tend to be short and slim. The rice in the low-altitude areas has a higher efficiency of photosynthesis, which reveals that the efficiency of photosynthesis tends to reduce with the increase of altitude (Li and Lin, 1986). Effect of elevations on plant growth tends indirectly, meaning that the difference elevation will affect the environment by temperature, humidity, oxygen in the air, and soil conditions.

Maturity day is an important phenological character observed in the experiment. Most of the tested varieties have medium type of maturity days (132-138 days) in higher altitudes. Out of six tested varieties the earlier maturing variety was Sukhadhan-2 with higher grain yield. The early maturing variety is the beauty for increasing cropping intensity in the hilly areas. Yan et al. (2007) reported that the safe day for the rice growth is 130 days, when the accumulated temperature of the growth of rice (growing degree days) will decrease along with the increase of the altitude. When the altitude is more than 900 meters, there are no more than 120 days with an average temperature above 20°C, and about 150 days above 15°C. The short duration

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variety such as Sukhadhan-2, Sukhadhan-4 and Sukhadhan-6 can increase the cropping intensity and total income of the farmers in mid hills.

The mean panicle length of most of the tested varieties were about 20.5 cm length and the final grain yield of these varieties is below 4 tons per hectare. Grains number and their effectiveness are major characteristics of any panicle. The differences in growth characters due to genotypes may be attributed to their inherent characteristics. The findings corroborate with those of Thomas and Lal (2012).Effect of altitude on panicle length showed that longest panicle was produced in lower altitude compare to higher altitude . In higher altitude areas due to low temperature during panicle development the panicle length, number of effective grains per panicle and final yield is directly influenced. In higher altitude, the humid conditions favour different types of disease development and the cold spells during anthesis cause spikelet sterility.

The highest number of effective tillers per m^2 was found in Sukhadhan-2 (238 tillers) showed direct influence on highest grain yield (2.93 t/ha) compared to other varieties. Effective tillers per unit area are good yield attributing characters of rice. The development of effective tillers is varietal character to some extent but emergence and development of rice are primarily influenced by the climatic factors such as temperature, light hours and rainfall .The higher altitude influenced the number of effective tillers per hill.

The highest numbers of effective grains per panicle was found in Sukhadhan-2 (83 grains) followed by Sukhadhan-5 (80 grains and Sukhadhan-3 (76 grains) which is reflected on higher grain yield. The lowest grains per panicle were found in Sukhadhan-6 (68 grains). Yield attributing characters like no. of panicle/m^2, panicle length, and effective grains/panicle, varied significantly due to varieties. These results are in agreement with the findings of Tiwari *et al.* (2015). Similarly, in case of altitudinal effect, the highest number of effective grains per panicle was found in 1000 masl (87 grains) whereas the lowest number of effective grains per panicle was observed in 1600 masl (65 grains) which reflect lower grain yield. In higher altitude areas, the sterility percentage of grains was found higher because of high pollen mortality caused by low temperature and drought at the time of flowering. Grain yield reduction is mainly due to reduction in effective tiller number, panicle initiation, spikelet fertility.

Regarding to sterility percentage of tested varieties, the highest sterility was observed in Sukhadhan-6 (31.93%) followed by Sukhadhan-3(30.97%) while lowest sterility was in Sukhadhan-2 (27.93%) which reflects on final grain yield. Good drought and cold tolerant ability and high production potentiality of Sukhadhan-2 might be the reason of high yield compared to other varieties. Kamoshita *et al.* (2008) reported that genotypes adopted to rainfed lowland areas having drought resistant capacity produced higher yield. In high altitude, less grain settings may occurs because of cold injury and high mortality percentage of pollen grains.

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Regarding to Grain yield, maximum grain yield was obtained from Sukkhadhan-2 (2.93 t/ha) and Sukhadhan-5 (2.92 t/ha) followed by Sukhadhan-3 (2.82 t/ha) while lowest yield obtained from Sukhadhan-6. Good drought resistant and in some extent cold tolerance potentiality of Sukhadhan-6 might be good characters of Sukhaadhan-2. The highest grain yield in lower altitude might be due to high photosynthetic efficiency, less pollen mortality and good grain setting. The effect of drought stress depends on severity, duration and timing, plant responses and G x E interactions. The grain yield reduction of Sukhadhan-6 is mainly due to reduction in effective tillers number, less spikelet fertility, reduction in plant height, biomass, test weight, and harvest index were also negatively influenced by drought and cold temperature in higher elevation while it was found tolerable in some extent in case of Sukhadhan-2 and Sukhadhan-5.

There is significance on interaction effect of variety and altitude on grain yield. The grain yield of almost varieties was found higher in lower altitude areas compared to high altitudes. Low yield in high altitude areas might be due to low temperature during growth and reproductive period. High sterility percentage in high altitude might be the less yield due to less grain setting, less filled grains per panicle, less test weight and less grain yield.

CONCLUSION

The rice varieties Sukhadhan-2 and Sukhadhan-5 gave the good performance in drought and cool environments found in altitude of 1000 m. The highest grain yield in these rice varieties was due to their good yield attributing characters such as high number of effective grains per panicle, less sterility percentage, high number of effective tillers per unit area, good test weight, and higher harvest index. Rice yield was found the highest at lower altitude of 1000 m as compared to subsequent higher altitudes. The highest yield in lower altitude was due to high photosynthetic efficiency, less pollen mortality and good grain setting. Thus rice production can be maximized by growing them in altitude of 1000 m.

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Authors contribution

S. Dhakal	Designed and performed experiment, analysed data and wrote the paper
B. B. Adhikari	Guide to conduct research and writeup paper and edit the manuscript
B.P. Kandel	Wrote and edit manuscript

Conflict of interest

The authors declare that there is no conflicts of interest regarding publication of this manuscript.

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