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Effect of different Altitudes in Qualitative and Quantitative Attributes of Green Coffee Beans (*Coffea arabica*) in Nepal

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***Abstract*— *A study entitled "Effect of different altitudes in qualitative and quantitative attributes of green coffee beans in Syangja district" was conducted to study the variation in quality and quantity of coffee produced within different altitude. The experiment was laid out with seven treatments with ranges of altitude as T1= (800-900) masl, T2 = (900-1000) masl, T3 =(1000-1100) masl, T4 = (1100-1200) masl, T5 = (1200-1300) masl, T6 = (1300-1400) masl and T7 = (1400-1500) masl and each was treated in four different clusters of coffee orchards which replicated the sample four times. From each cluster a sample of 500gm ripe cherries were taken for individual treatment and processed by wet method for Parchment formation followed by its dehulling to form green coffee beans. Parameters like 1000cherry weight, Parchment weight, Green bean weight, Bean density, Parchment recovery, Caffeine content, Productivity and Consumer preference were estimated from a total of 28coffee samples. It was observed that the altitude range of (1400-1500) masl showed maximum mean value of 1000 cherry weight (1989.25±104.19) gm, Parchment weight(126.5±2.38)gm, Green bean weight (105±2.954)gm, Green bean density(687.5 ±8.18)kg/m 3 and Productivity (31.7±2.69) t/ha whereas minimum mean value of caffeine content (1.0285 ±0.02)%. Maximum preference score (0.772) was observed in coffee sample of highest altitude (1400-1500) masl which was given by a team of five persons of coffee experts and consumers. However the effect of treatment seemed insignificant for parchment recovery. With increasing altitude, attributes that depict the quality and quantity of coffee was found to be increasing except the caffeine content. Hence, the higher altitude range 1200masl and above seemed to be instrumental for quality coffee production.*

***Keywords*— Parchment, Altitude, Coffee, Caffeine.**

I. INTRODUCTION

Agriculture is the main source of livelihood for the majority of people in Nepal and is considered as the primary engine of growth of the economy. The agriculture sector contributes 26.24 % of Gross Domestic Product (GDP) and has become a way of life for 65% of people in Nepal [1]. Horticulture sector contributes 14% to the total Agriculture Gross Domestic Product (AGDP) [2]. Nepal being rich in climatic diversity, there is wider scope for the production of various types of fruits and vegetables. Horticultural crops can contribute in food security, improve nutritional status and provide employment opportunities; increase income and thus increasing overall GDP of the country [3]. Among various horticultural commodities of Nepal, coffee is also an important crop having great scope in international market.

Coffee is an important cash crop for millions of farmers in more than 50 countries and has its huge significance for the prospects of daily use as beverage and it also has high export value from Nepal [4]. Coffee is a rich source of alkaloids such as caffeine, trigonelline, theobromine, theophylline and their profile in green coffee beans is important and helpful to know the quality of coffee brew [5]. Coffees are mainly grown in the mid hill region of Nepal at an altitude of 800-1600 msal [6]. Nepal produces 434 metric ton of green bean under the area of 2618 ha [2]. Basic coffee growing districts of Nepal are Syangja, Gulmi, Kaski, Palpa, Arghakhanchi, Pyuthan Kavre, Lalitpur, Sindhupalchock. Among these Syangja is the largest coffee producing district-having 310 hectares area under coffee plantation producing over 41 metric ton of green bean [2].It is an evident fact that production of coffee is in increasing trend in Nepal. Transaction of the coffee produced in Nepal is done in bulk without adopting measures to grade and assure the quality of coffee. Risk of coffee production could be clarified by the fact that there is constant increase in area under coffee production but decline in productivity over past 10 years [6].Government of Nepal has enacted National Coffee Policy (2003) to commercialize coffee farming with special focus on human resource development and mechanization; however, it lacks policy on organic agriculture pocket development and area expansion [7]. There is prediction of area reduction by 72% due to climate change by 2050 [8]. Poor resource allocation per region, linking crop altitude ranges to quality and quantity parameters. Furthermore farmers are not much concerned about alteration in quality of coffee with respect to domain due to which they are not being able to judge their products and the actual value that they should receive. In near future if international consumers of Nepalese coffee start importing coffee produced here by quality assessment, it may face the risk of market as growers of coffee in Nepal are unaware to the quality status of their coffee.This study focuses on accessing altitudinal effect on Coffee quality as well as quantity and identification of best altitude for commercial quality coffee production. Domain wise consumer preference of coffee among Coffee growers, experts and consumers is also evaluated by this study. It will help farmers to adopt improved orchard management practices as well as processing method for production of optimum quality coffee. Marketing potential using characteristics of coffee that come from specific producing regions will be accessed from this study.

II. MATERIALS AND METHODS

The study was conducted at putalibazzar municipality of Syangja where samples from different altitudes of Syangja were analysed. Coffee orchards at north facing slope were selected with elevation differences of 100 meters. The experimental orchard is characterized by warm temperate climate receiving standard horticulture care. Furthermore, sites with similar soil fertility status were selected with the help of data of soil survey done from Citrus super zone and Agriculture knowledge center Syangja.

1.1 Climatic condition:

This district has tropical climate with hot dry summer, moderate rainfall and cold winters with mean annual temperature between 31.5ºC and 6ºC. Most of the precipitation here falls in July and annual average rainfall is 2665 mm. Out of total area, 62.48 % (72,731 ha) of the area falls under cultivable land, 27.22 % (31,691 ha) under forest area and 10.28 % (11,978 ha) area under others.

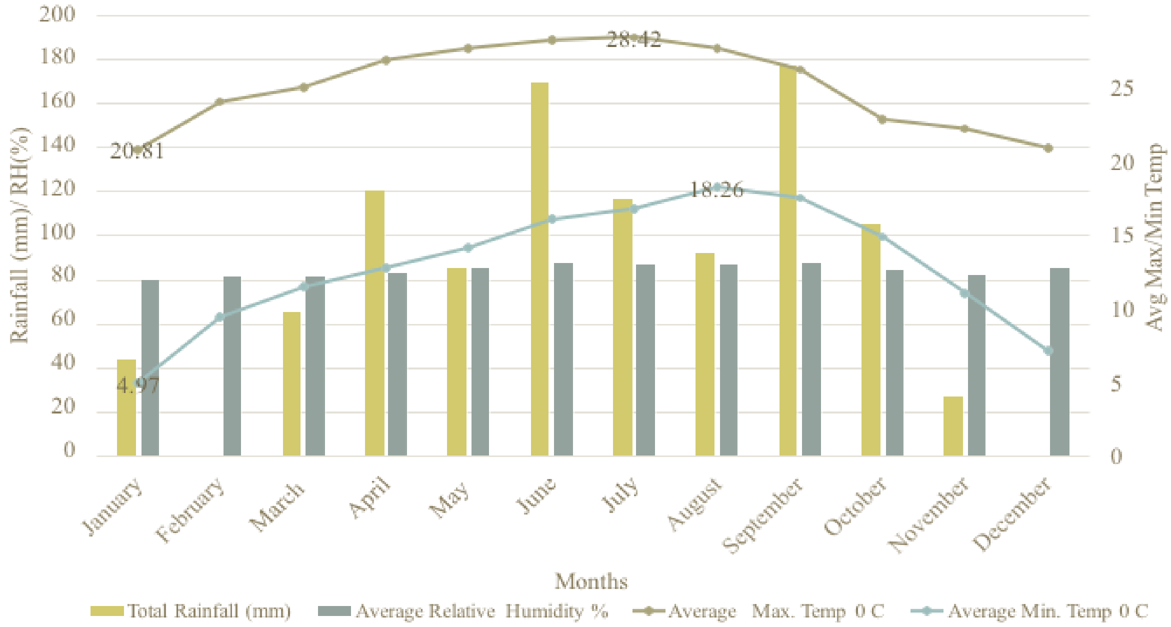

Fig.1: Meteorological data of research station

1.2 Sample and sampling technique:

Ripe coffee cherries samples were collected from middle branches of healthy coffee plants of 10-12 years age. A total of 28 ripe coffee cherries samples were collected from the coffee plant grown at altitudes of 800-1600 masl from different places. Different altitudes were ranged and located with the help of digital altimeter and taken as treatment.

1.3 Treatment Details:

T1	800-900 masl
T2	900-1000 masl
T3	1000-1100 masl
T4	1100-1200 masl
T5	1200-1300 masl
T6	1300-1400 masl
T7	1400-1500 masl

Each treatment consists of four clusters which act as replication. From each cluster of a treatment 500 g of green coffee sample was collected. All of the green coffee bean samples were processed by wet method of coffee processing where ripe cherries collected were pulped after 4 hours of collection to form parchment with mucilage. Fermentation of parchment with mucilage was done for 36 hours to form dry parchment which was dried for one week to maintain moisture content 12%. Hulling of the sample was done to obtain green coffee beans. All the samples were from the same harvest season and were collected throughout March 2019. Half of the samples were stored separately in plastic bags under airtight conditions and transported to the laboratory for chemical analysis whereas remaining half samples were medium roasted at 200^0C followed by their grinding and provided to taste panel for organoleptic taste.

Fig 2. GIS location of sample plot

III. RESULT AND DISCUSSION

1.4 Thousand cherry weight:

Thousand cherry weight of coffee increased significantly with the increase in altitude. The maximum value of thousand cherry weights (1989.25±104.19) was observed in the altitude range of (1400-1500) masl followed by range of (1300-1400) where weight was (1731.75±98.35) which was statistically at par with altitude range of (1300-1400) masl, (1200-1300) masl, (1100-1200) masl and (1000-1100) masl. The minimum thousand cherry weight (1433.75±41.51) was observed in the altitude of (800-900) masl.

Increasing altitude causes a decrease in ambient temperature and an increase in berry maturation process and hence allows more time for bean filling [9]. More time for bean filling aided in enhancing the weight of cherries in higher altitude. (Tolessa, 2016)found the weight of 100 cherries as 133, 147 gm at lower altitude range of (800-850) masl and 179, 161 gm at higher altitude range of (1600-1650) masl in UK.

Table 1: Effect of different altitude in thousand cherry weights (gm) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	1433.75±41.51^{c}
900-1000	1457±53.50^{c}
1000-1100	1620±73.48^{b}
1100-1200	1682±50.75^{b}
1200-1300	1687.5±63.97^{b}
1300-1400	1731.75±98.35^{b}
1400-1500	1989.25±104.19^{a}
SEm	35.38
Lsd(0.05)	108.27
CV, %	4.4
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= meter above sea level

1.5 Parchment weight:

The effect of different range of altitude is highly significant in mean value of parchment weight of coffee as shown in Table 4 and appendix 1b. The maximum Parchment weight (126.5±2.38) was observed in the altitude range (1400-1500) masl followed by (1300-1400) masl. Similarly, the minimum mean value of parchment weight(103.5±4.93) was observed in lowest altitude range (800-900) masl.

Altitude favored the production of beans with large size and weight, an indication of high accumulation of fat matter [9], [11] & [12] which was due to decrease in ambient temperature and an increase in berry maturation process and hence allows more time for bean filling [9]. Longer duration for bean filling in higher altitude enhanced the weight of coffee parchment.

Table 2. Effect of different altitude in Parchment weight (gm) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	103.5±4.93^{d}
900-1000	113±3.56^{c}
1000-1100	115.75±2.75^{bc}
1100-1200	116.75±4.19^{bc}
1200-1300	119.5±6.60^{bc}
1300-1400	122±3.36^{ab}
1400-1500	126.5±2.38^{a}
SEm	1.48
Lsd(0.05)	6.223
CV, %	1.48
P-value	3.5891***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= meter above sea level

1.6 Green Bean Weight:

Highly significant result was obtained in mean green bean weight of coffee with different altitude. The maximum green bean weight (105±2.94) was observed in the altitude range (1400-1500) masl followed by (1300-1400) masl. Similarly, the minimum mean value of parchment weight (85.25±4.27) was observed in lowest altitude range (800-900) masl.

In higher altitude, coffee plants take more time to mature as the ambient temperature is less and prolonged maturation phase helps to provide more time for bean to fill with it’s biochemical constituents like Sugar, fats and acids [9]. More time for bean filling increases the weight of green beans in higher altitude.

Table 3. Effect of different altitude in Green bean weight (gm) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	85.25±4.27^{d}
900-1000	93.5±2.65^{c}
1000-1100	94.75±2.87^{c}
1100-1200	97.75±3.59^{bc}
1200-1300	101.25±4.5^{ab}
1300-1400	102.5±3.79^{ab}
1400-1500	105±2.94^{a}
SEm	1.33
Lsd(0.05)	5.317
CV, %	3.68
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= meter above sea level

1.7 Green Bean Density:

Highly significant result was obtained in green bean density of coffee with different altitude. The maximum green bean density (687.5±8.18) was observed in the altitude range (1400-1500)masl followed by (1300-1400)masl. Similarly, the minimum mean value of density (619.75±13.72) was observed in lowest altitude range (800-900) masl.

Altitude causes a decrease in ambient temperature and an increase in berry maturation process and hence allows more time for bean filling [9]. More time for bean filling aided in producing heavier and denser coffee beans. Altitude favors the production of beans of large size and weight thereby making coffee beans denser.(Mutua, 2000)has mentioned the bean density of coffee ranges from 310-800 kg/m^3 at various stage of processing.

Table 4. Effect of different altitude in Green bean density (kg/m^3) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	619.75±13.72^{f}
900-1000	632.25±7.18^{e}
1000-1100	642.75±4.34^{de}
1100-1200	652±5.47c^{d}
1200-1300	662±5.22^{bc}
1300-1400	670.25±6.02^{b}
1400-1500	687.5±8.18^{a}
SEm	4.32
Lsd(0.05)	11.497
CV, %	1.19
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= meter above sea level

1.8 Parchment recovery (%):

The mean parchment recovery (%) in all the altitude was statistically similar. Percentage of parchment that could be converted into green coffee beans was found to be insignificant in relation with varying altitude. Quality and biochemical composition of green beans changes with altitude [10]. Parchment recovery had statistically similar values at different altitude which may be due to unchanged biochemical composition of husk at different altitude.

Table 5. Effect of different altitude in Parchment recovery (%) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	82.38±2.17
900-1000	82.75±1.24
1000-1100	81.86±1.63
1100-1200	83.73±1.34
1200-1300	84.79±2.39
1300-1400	84.02±2.44
1400-1500	83.00±1.50
SEm	0.36
Lsd(0.05)	NS
CV, %	2.25
P-value	0.4403

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; NS= Non Significant; P-value= Probability, SD = standard deviation, masl= meter above sea level

1.9 Caffeine content:

The maximum value of caffeine content (1.28±0.01) was observed in lowest altitude (800-900) masl followed by (900-1000) masl which was statistically at par with (1000-1100) masl. On contrary, the altitude range of (1400-1500) masl shows lowest caffeine content (1.0285±0.02).

Altitude causes a decrease in ambient temperature and an increase in period of berry maturation [9].In coffee bean development, biosynthesis and accumulation of most of the chemicals including caffeine is marked higher at early stage of development and reported to be lower at ripening stages [14]. At later stage of bean development compounds like Caffeine are remobilized towards lignin biosynthesis thereby decreasing its content [15]. More caffeine will be converted into compounds like Chlorogenic acid, sucrose and fat with the increase in altitude [16]. (Benoit & Vaast, 2006)Evaluated caffeine content of (700-899) masl, (900-1099) masl, (1100-1199) masl, (1200-1399) masl, (1400-1600) masl as 1.2, 1.19, 1.17, 1.13 and 1% (w/w) respectively.

Table 6. Effect of different altitude in Caffeine content (%w/w) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	1.28 ± 0.01^{a}
900-1000	1.256 ± 0.007^{ab}
1000-1100	1.2403 ± 0.005^{ab}
1100-1200	1.2263 ± 0.0059^{b}
1200-1300	1.2165 ± 0.015^{b}
1300-1400	1.096 ± 0.069^{c}
1400-1500	1.0285 ± 0.02^{d}
SEm	0.02
Lsd(0.05)	0.042
CV, %	2.404
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= meters above sea level

3.7 Productivity:

Altitude range (1400-1500) masl showed maximum productivity (31.70±2.69) and productivity decreased with decrease in altitude. Lowest altitude range (800-900) masl shows least productivity (13.41±0.611).

Altitude causes a decrease in ambient temperature and an increase in berry maturation process and hence allows more time for bean filling [9]. Heavier and denser beans at are produced from higher altitudes within similar varieties of coffee justifies higher productivity of coffee orchards in higher altitude. Belete et al, 2014 found the weight of productivity of coffee orchards at 1550, 1600, 1753, 1940 masl as 824, 1391, 1512 and 1993 respectively kg per hectare in Ethiopia [18].

Table 7. Effect of different altitude in Productivity (tons/ha) of coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	13.41 ± 0.611^{f}
900-1000	14.90 ± 0.46^{f}
1000-1100	17.22 ± 1.37^{e}
1100-1200	19.51 ± 1.09^{d}
1200-1300	22.05 ± 1.65^{c}
1300-1400	26.62 ± 1.40^{b}
1400-1500	31.70 ± 2.69^{a}
SEm	1.19
Lsd(0.05)	2.219
CV, %	7.190
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV= coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= metre above sea level

3.8 Consumer Preference:

Maximum preference score (0.772) was observed in coffee sample of highest altitude (1400-1500) followed by the altitude range (1300-1400) masl which was statistically at par with (1200-1300) masl. The minimum preference score level was obtained in sample of altitude range (800-900) masl.

Altitude favored the production of beans of large size and weight, an indication of high accumulation of fat matter and increased chlorogenic acids and fat content in *C. arabica*. This fat accumulation enhanced the intensity of organoleptic characteristics such as aroma, body, acidity, flavor and preference [19]. Fat content was associated positively to coffee quality, while Caffeine, trigonelline and sucrose were associated negatively to with organoleptic quality, chlorogenic acids presented intermediate characteristics [19].

Table 8. Effect of different altitude in Consumer Preference on coffee in Syangja district

Treatment(Altitude in masl)	Mean±SD
800-900	0.56^{d}
900-1000	0.58^{cd}
1000-1100	0.63^{cd}
1100-1200	0.72^{ab}
1200-1300	0.67^{bc}
1300-1400	0.74^{ab}
1400-1500	0.772^{a}
SEm	0.667
Lsd(0.05)	0.089
CV, %	9.16
P-value	<0.001***

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; Sem = Standard error of means; CV=

coefficient of variation; LSD= least significant difference value at 5%; P-value= Probability, SD = standard deviation, masl= metre above sea level

IV. CONCLUSION

Effect of altitude on various qualitative as well as quantitative parameters was found to be significant. However the effect of treatment seemed insignificant for parchment recovery. With increasing altitude, attributes that depict the quality and quantity of coffee was found to be increasing except the caffeine content which was decreasing. Such variation with the altitudinal increment was observed due to decreased ambient temperature which prolonged maturation period of coffee and aided in increased Sucrose as well as fat accumulation inside beans making it heavier and denser. Decrease in caffeine content with increasing altitude was due to increasing content of photosynthetic accumulates like sucrose, fat and chlorogenic acid converted from caffeine during ripening period of coffee. Production of large and dense coffee with little defect is prerequisite for quality coffee. From the consumer point of view less caffeine content, higher will be the sensory quality as caffeine is related with bitterness. It is an evident fact that for optimum production of quality coffee, high altitude range are suitable but in the meantime those domain may have topographic constrains. Hence, the higher altitude range 1200masl and above seemed to be instrumental for quality coffee production.

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