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Abstract: This study was conducted to assess the comparative economic analysis of the High density and conventional systems of apple cultivation. It also aimed to compare crop managerial practices in two cultivation systems and major problems involved in the production of apples in the study area. A total of 125 farmers from two districts, Manang and Mustang, were selected by simple random sampling technique and interviewed with a pre-tested semi-structured interview schedule of which 60 were HDP practitioners and 65 were conventional practitioners. Chi-square test and independent sample t-test were used for data analysis using SPSS and MS-Excel. Drip irrigation system, regular training pruning, low weeding frequency, chemical source of nutrient management were some distinguishing managerial practices in the high-density plantation system. Pit manuring, flooding irrigation, intercropping, high weeding frequency were found to be more common in the conventional system. Unavailability of saplings and fertilizers (0.79) and lack of

ABOUT THE AUTHOR
The author Miss. Rojina Kafle was born on 25 June 1998 in Kathmandu, Nepal. She completed her First Degree in Agricultural Science at Forestry University (AFU), Chitwan, Nepal in 2020. The author got an opportunity to pursue internship under Learning Entrepreneurial Experience (LEE) program through AFU and Prime Minister Agriculture Modernization Project (PMAMP) under Government of Nepal in Apple Zone, Mustang, Nepal. She has received number of training and attended many workshop and seminar. She has also been actively involved in Climates Nepal as climate activist. The research on comparative economic analysis of the High density and conventional systems of Apple cultivation relates to livelihood of Nepalese people and economy of the country as this research assists farmers to invest in cultivation system with high profitability.

PUBLIC INTEREST STATEMENT
The ecological conditions in the Himalayan region provide a unique opportunity to the farmers in Nepal to sell their apples in the global market. The study was conducted to compare the economic aspects and managerial practices of high-density and conventional systems of apple cultivation. Findings revealed that drip irrigation system, regular training pruning, low weeding frequency, chemical source of nutrient management, were distinguishing managerial practice in the high-density plantation system. Pit manuring, flooding irrigation, intercropping, high weeding frequency were found to be more common in the conventional system. Unavailability of saplings and fertilizers and lack of post-harvest storage were major problems reported by high-density practitioners and conventional practitioners respectively. Economic analysis revealed increasing benefit-cost ratio in the high-density plantation system, even when being in the initial establishment phase. These findings thus clearly hint that promotion of high-density plantation system would be needed at farm level to uplift the income of farmers.
post-harvest storage (0.76) were major problems reported by high-density practitioners and conventional practitioners respectively. The economic analysis revealed a benefit-cost ratio of 0.35, 0.80, and 1.39 in the HDP system and benefit-cost ratio of 1.60, 1.68, and 1.72 in the conventional system for the years 2017, 2018, and 2019 respectively. The increasing benefit-cost ratio in the high-density plantation system, even when being in the initial establishment phase can be expected to be more profitable when all plants reach the full production phase. The conventional system is still profitable but high density is promising as it can give more profit per unit of land.

**Subjects:** Agriculture & Environmental Sciences; Education - Social Sciences; Economics

**Keywords:** Apple; benefit-cost ratio; conventional; economic analysis; high-density; managerial practice

1. **Introduction**

Apple (*Malus domestica* Borkh.) is a major crop contributing to the total volume of temperate fruit produced in terms of area and production. Apple stands as the second most cultivated temperate fruit, after the grape, in terms of area and stands at the top in terms of production among temperate fruits in the world (FAOSTAT, 2018). Apple is primarily cultivated in 41 districts of Nepal. The total area for the production of apples in Nepal is 11,186 ha, cultivated in 4349 ha and total production is 31,386 Mt with the productivity of 7.22 Mt ha$^{-1}$ (MOALD, 2019). The productivity of Mustang (12.8 Mt ha$^{-1}$) and Manang (12.4 Mt ha$^{-1}$) is highest among apple cultivating districts of Nepal. Nepal produced 19,850 metric tons of apples per annum, most of which are being consumed locally. Trade figure shows that Nepal imported 79,876 metric tons of apples worth IINR 4 billion from China, 13,413 Mt apple worth INRINR 937 million from India and 185 Mt worth INRINR 26 million from United States (DoC, 2018). The trend of apple production shows that the production of apples in Nepal is increasing, however, increased production is due to an increase in the cultivation area (Thapa et al., 2004). Since the expansion of the production area is bound to limitation, productivity should increase to facilitate production.

In the last 60 years, the traditional production system, that used standard trees with wide spacing, has been replaced by a high-density plantation system, which uses dwarf trees with close spacing (Robinson, 2011). The global trends show that the intensification in plantations with a high-density plantation system contributes to higher yield and production per unit area (Dhiman, 2018). High-Density Planting system is a novel cultivation technique in which a higher number of plants are accommodated within a unit area in comparison to conventional planting density (Goswami et al., 2014). High-Density Plantation system accommodates more than 1000 plants per ha. Besides, precocity (coming to fruit-bearing within 1–2 years) is the essence of the system which is a function of dwarfing rootstock, such as Mailing series rootstocks: M9, M7, M2.6, etc. (Parker, 1998; Rom & Stasiak, 1990). Such high density reduces yield ha$^{-1}$ but increases yield per unit area significantly (Hampson et al., 2002). Even with clear economic benefit, rootstock susceptibility to Fireblight is a major limitation associated with high-density planting system (Russo et al., 2007). Moreover, maintenance of HDPs requires regular technical assistance, strict training and pruning, and chemicals to maintain optimum growth (Majid et al., 2018).

Conventional apple plantation system uses standard type tree apples grafted on seedling rootstocks and accommodate 100–500 plants ha$^{-1}$ (Majid et al., 2018). Seedling rootstocks are mainly produced from seeds obtained from apple plants and are generally “Delicious” cultivar. Such trees on seedling rootstocks are considered full-sized trees (standard type), which was a common apple type of orchards around the world before the advent of the clonal rootstock. The trees when well pruned, on maturity, attain a height of 16–18 feet with a canopy diameter of about 13–16 feet.
Longevity, cold-hardiness and resistance to serious disease problems are some of the advantages of trees borne on seedling rootstocks.

In 2015, Agro-Manang Private Limited, Manang imported Gala, Golden Delicious and Fuji varieties grafted on dwarfing rootstock (M9T337) from Nischler Company, Italy, and established high-density apple orchard (3333 trees ha$^{-1}$) for the first time in Nepal (Subedi et al., 2020). Thereafter, high-density apple garnered the attention of farmers and government organizations. Prime Minister Agriculture Modernization Project-Nepal (PMAMP) has focused on prioritizing HDP and has been distributing saplings at a subsidized rate to promote high-density plantation in apple. However, the reluctance of farmers to adopt modern technology is another problem in apple production (FDD, 2017). The requirement for high initial investment and other technical aspects associated with it might dissuade the farmers. However, little efforts have been made about comparative analysis of two systems to determine of profitable plantation system. It can't be denied that both the cultivation systems are bound to some advantages and disadvantages, and the managerial aspects of the cultivation system underpin the fate of the cultivation system. Hence, this study seeks to access the managerial aspects of high density and conventional apple cultivation system. Besides, it aims to provide the economic assessment of the systems which could help to decide between two cultivation systems of production.

2. Materials and methods

The study was conducted in Mustang and Manang, the two high hilly districts of Western Nepal, from January to March 2019. This region is a prominent apple producer and is considered a pioneer of apple cultivation in the country. Thasang, Gharabjong, Baragau and Da La Me rural municipalities from Mustang and Chame, Nason, and Ngisyang rural municipalities of Manang were purposively selected for the study because they are major apple-producing areas within the region where high-density plantation of apple is in practice. There were altogether 140 apple growers registered under PMAMP-apple zone, Mustang, and 68 apple growers registered under PMAMP-apple zone, Manang within the selected locations. In the study, 125 farmers were surveyed for collection of information through simple random sampling technique. Out of which 65 (35 from Mustang and 30 from Manang) farmers were Conventional System practitioners and 60 (30 from each district) were High-Density Plantation (HDP) System practitioners. However, only 105 apple producers–65 of them who were practicing conventional cultivation system; and 40 of them who were practicing HDP system, and who had started getting produce for 2 years or more–were purposively considered for economic analysis.

A total of four focus group discussions were conducted in Thasang, Gharabjong, Baragau and Da La Me rural municipalities of Mustang using FGD checklist with progressive farmers, ward representatives, members of the zone management committee. Key informants such as progressive farmers (2), plantation material suppliers (2), members of the zone-management committee (4) were asked for cross verification of the responses of respondents.

The information collected by the household survey, focus group discussion and key informants survey was coded and entered in MS-Excel and analyzed using SPSS. Inferential statistics like t-test and chi-square test were done for the analysis.

2.1. Conceptual issues in economic analysis

Even though HDP system of apple cultivation has been in practice for over many years. It is the system which, only recently, has been garnering attention among farmers across Nepal, and is still in juvenile phase wherever being practiced in the country. At present, the majority of HDP orchards are in the initial establishment phase and, hence economic information of 40 practitioners who have been receiving yield for the last 2 to 3 years or above have been considered for economic analysis while the cost and return information of all 65 conventional practitioners have been considered for economic analysis. Moreover, every cost and return information have been converted to cost and returns ha$^{-1}$, and averaged for the last three years (from 2017 to 2019 A.D.) to better reveal the existing scenario of two cultivation system under practice in the study area.
2.2. Economic analysis

The cost incurred in clearing plantation area, pit digging, plantation, trellising, plant saplings, drip installment, and fencing comprises the total establishment cost (TEC).

Amortized cost supposedly behaves as the fraction of TEC that is at stake for each year along the crop life span; such that it is even possible to obtain Net return by subtracting amortized cost and variable cost from gross return. The amortized cost was calculated by using the method followed by Merritt (2013).

Amortized Cost = TEC ((1 + i) AL*i/(1 + i) AL-1

Where,

TEC = Total establishment cost

i = interest rate of 12% is taken

AL = Average life span of apple (According to Dorin et al. (2015), the life span of HDP is 20 years; and conventional apple is 30 years)

Total variable cost (TVC) consists of the cost incurred for manure, fertilizers, plant protection chemicals, and labor cost (manuring, spraying, weeding, training pruning, irrigation, thinning, harvesting and packaging).

Gross return (INR ha⁻¹) was calculated by using formula used by Dillon and Hardaker (1993) as product of total volume (kg) of apple produced and existing farm gate price (INR kg⁻¹)

Gross margin was calculated by using the formula as used by Olukosi et al. (2006)

Gross margin (INR ha⁻¹) = Gross return (INR ha⁻¹)-Total Variable cost (INR ha⁻¹)

According to Gangwar et al. (2008), the benefit-cost ratio of apple cultivation in two cultivation system has been calculated by dividing the total return by total cost (Amortization cost, the rental value of land, and maintenance cost)

BC Ratio = Gross Return/Total cost

The annual land rental value was taken as INR160000 per ha⁻¹ though maximum farmers had their own land.

3. Indexing and scaling

Different reasons for difficulties in apple production based on farmers’ perceptions were analyzed by using five-point scales of problems. A forced ranking scale was used for scaling by giving a score of 1 to the most severe problem and ascending score for less severe problems.

The index of importance was computed by using the following formula.

I imp = Σ (Si Fi/N),

Where,

I imp = Index of importance

Si = Scale value at iᵗʰ severity
Fi = Frequency of importance given by respondents

N = Total number of respondents

4. Results and discussion

4.1. Crop managerial practices

Table 1 presents years of experience of farmers in apple cultivation and age of plants in two different systems. The years of experience in apple cultivation were found higher among conventional practitioners (24.97 yrs) than that of HDP practitioners (20.75 yrs). The number of Plants of age 1–5 years was found higher (746.19) among HDP practitioners while it was only 108.57 among conventional practitioners indicating HDP system to be in the early establishment phase.

| Variable                              | HDP type (n = 60) | Conventional type (n = 65) | Overall (N = 125) | Chi-square | t-value | P-value |
|---------------------------------------|-------------------|----------------------------|--------------------|------------|---------|---------|
| Household experience in apple cultivation (yrs.) | 22.93(7.053)      | 20.72(5.749)               | 24.97(7.554)       | -4.253***  | -3.519  | 0.001   |
| Household experience in apple cultivation (yrs.) | 616.89(393.332)   | 746.19(333.988)            | 108.57(56.95)      | 683.165*** | 7.006   |         |

Notes: Figures in parentheses resemble standard deviation. *** indicates level of significance at 1 percent.

Table 2 presents comparison of crop managerial practice between HDP and conventional practitioners. 100% of the HDP practitioners used M9 as rootstock while 81.5% and 18.5% of conventional practitioners used crab apple and local wild rootstock respectively. Fuji, Red Delicious, Golden Delicious, Gala and their mix-up were used as scion and there was no significant difference between two cultivation systems in terms of scion cultivar selection. Central leader and tall spindle among HDP practitioners and open-center and modified central leader were prominent training system. Two private companies – Agro-manang and Swarnim multinational – were major exporter and supplier of HDP plant saplings while farmers used to obtain conventional system plant saplings through own source and government organization.

Similarly, pit manuring was more common among conventional practitioners (97%) than HDP practitioners (71.7%). As reported by apple growers, fertigation was more common in high-density plantation so few HDP practitioners performed pit manuring with organic manure. Among conventional practitioners, 23.1%, 44.6% and 32.3% depended on commercial organic manure, FYM and FYM-chemical respectively for fertilization. While, among HDP practitioners, 53.3%, 31.7% and 15% depended on chemical fertilizer, FYM-chemical and commercial organic manure respectively for fertilization. It was evident that chemical sources in HDP system and organic sources in conventional system were major nutrient management practices (Table 3). 83.3% of HDP practitioners practiced irrigation through drip method while ring and surface flooding method was common among conventional practitioners. 36.7% of HDP practitioners practiced intercropping while 86.2% of conventional practitioners performed intercropping in their orchard. 91.7% of HDP practitioners performed regular training pruning and 55.4% of conventional practitioners performed regular training pruning. It was found that thinning of flower buds was peculiarly practiced in HDP system and no conventional practitioners performed such operation. Also, conventional system required frequent weeding. 100% of HDP practitioners reported problem of insect pests while 96.9% of conventional practitioners reported insect pests in their orchards.
Table 2. Comparison of crop managerial practice between HDP and conventional practitioners

| Variables                   | HDP type (n = 60) | Conventional type (n = 65) | Overall (N = 125) | Chi-square | P-value |
|-----------------------------|-------------------|---------------------------|-------------------|------------|---------|
| Pit-Manuring (Yes/No)       | 43(71.7)          | 61(93.8)                  | 104(83.2)         | 10.981***  | 0.001   |
| Irrigation Method           |                   |                           |                   |            |         |
| Ring Method/ Flooding       | 10(16.7)          | 65(100)                   | 75(60)            | 92.090***  | 0.000   |
| Drip Irrigation            | 50(83.3)          | 0(0.0)                    | 50(40.0)          |            |         |
| Intercropping (Yes/No)     | 22(36.7)          | 56(86.2)                  | 78(62.4)          | 72.343***  | 0.000   |
| Regular-Training Pruning (Yes/No) | 55(91.7) | 36(55.4) | 91(72.8) | 20.741***  | 0.000   |
| Mulching (Yes/No)          | 7(11.7)           | 1(1.5)                    | 8(6.4)            | 5.343**    | 0.021   |
| Weeding Frequency           |                   |                           |                   |            |         |
| Twice a year                | 12(20)            | 0(0.0)                    | 12(9.6)           | 31.374***  | 0.000   |
| Thrice a year               | 33(55.0)          | 19(29.2)                  | 52(41.6)          |            |         |
| More than 3 times a year   | 15(25.0)          | 46(70.8)                  | 61(48.8)          |            |         |

Notes: Figures in parentheses resemble percentage to their respective columns. *** indicates level of significance at 1 percent. ** indicates level of significance at 5 percent.

Table 3. Comparison of nutrient management options among HDP and conventional practitioners

| Variable            | HDP type (n = 60) | Conventional type (n = 65) | Overall (N = 125) | Chi-square | P-value |
|---------------------|-------------------|---------------------------|-------------------|------------|---------|
| Nutrient Source     |                   |                           |                   |            |         |
| FYM                 | 0 (0.0)           | 29 (44.6)                 | 29 (23.2)         | 125.00***  | 0.000   |
| Chemical            | 32 (53.3)         | 0 (0)                     | 32 (25.6)         |            |         |
| FYM+ Chemical       | 19 (31.7)         | 21 (32.3)                 | 40 (32.0)         |            |         |
| FYM+ Organic Manure | 9 (15)            | 15 (23.1)                 | 24 (19.2)         |            |         |

Notes: Figures in parentheses resemble percentages to their respective columns. *** indicates level of significance at 1 percent.

5. Economic analysis

5.1. Establishment cost analysis

The cost incurred in clearing plantation area, pit digging, plantation, trellising, plant saplings, drip installment, and fencing comprises the total establishment cost (TEC). The total establishment cost in the HDP system (INR 3,839,322.30) was much higher than in the conventional system (INR 467,306.17) and was statistically significant at 1% level of significance.

The cost for the clearing plantation area in the HDP system (INR 73,424.46) was higher than the conventional system (INR 39,705.26) which was statistically significant at 1% level of significance. The cost for pit digging in the HDP system (INR 118,478.36) was higher than the conventional system (INR 63,608.60) which was statistically significant at 1% level of significance. The cost for planting saplings in the HDP system (INR 66,520.3) was higher than the conventional system (INR 16,466.53) which was statistically significant at 1% level of significance. The cost for drip installment was INR 566,762.78 in the HDP system. The cost of saplings in the HDP system (INR 1,949,435.54) was very higher than the conventional system (INR 28,176.18), a major contributor to the high establishment cost of HDP system,
which was statistically significant at 1% level of significance. The cost for fencing in the HDP system (INR 484,595.29) was higher than in the conventional system (INR 3,193,349.58) which was statistically significant at 1% level of significance. Similarly, the amortized cost for the HDP system (INR 484,967.02) was much higher than in the conventional system (INR 58,010.42) which was statistically significant at 1% level of significance.

6. Analysis of variable cost

6.1. Material cost
The cost of chemical fertilizer required in the HDP system (INR 28,238.99) was higher than the average fertilizer cost required in the conventional system (INR 1882.357) which was significant at 1% level of significance. It was found that chemical fertilizer is a major source of plant nutrient common among HDP practitioners as it is easy in application through fertigation. The cost of manure used in the HDP system (INR 80,904.92) was at par with the conventional system (INR 71,602.52). The accommodation of a large number of plants in the HDP system, though only about 5 kg per plant of manure is applied, and a small number of plants in the conventional system requiring 25–50 kg per plant manure account for such result. It was found that organic manure is a major source of nutrients among conventional practitioners. Similarly, the cost of plant protection chemicals in the HDP system (INR 23,960.926) was found statistically insignificant to the average cost of plant protection chemicals in the conventional system (INR 22,984.82).

6.2. Labor cost
In the study area, human labor was largely used as input in the production of apple which was computed in terms of the total value in monetary terms including the family members used as labor in the orchard. The cost of manuring in the HDP system (INR 25,076.81) was lower than the cost of manuring in the conventional system (INR 27,702.62) which was statistically significant at 10% level of significance. The cost of spraying in the HDP system (INR 14,679.77) was lower than the cost of spraying in the conventional system (INR 17,003.32) which was statistically significant at 5% level of significance. The cost of irrigation in the HDP system (INR 7735.00) was lower than the cost of irrigation in the conventional system (INR 11,900.00) which was statistically significant at 1% level of significance. The use of a drip irrigation system in the HDP system accounts for low irrigation costs in this system. The cost for weeding in the HDP system (INR 31,667.02) was less than the average cost for weeding in the conventional system (INR 41,396.48) which was statistically significant at 1% level of significance. Weed control due to the drip irrigation system in the HDP system and practice of weeding in circles around tree base along with hoeing in the conventional system account for the obtained result. The cost for training pruning of plants in the HDP system (INR 21,656.26) was lower than the conventional system (INR 36,953.02) which was statistically significant at 1% level of significance. The large trees in the conventional system and hence huge labor requirement for the practice account for the result. The harvesting cost (INR 44,325.55) and packaging cost (INR 16,871.804) in the HDP system was higher than the average harvesting cost (INR 22,297.39) and packaging cost (INR 9053.92) in the conventional system which was both significant at 1% level of significance.

While some of the managerial practices are common to both cultivation systems, thinning of flowers is often practiced in the HDP system. The total labor cost in the HDP system (INR 151,461.51) was lower than the conventional system (166,231.06) but was insignificant. The average variable cost in the HDP system (INR 284,566.35) was higher than in the conventional system (INR 262,700.77) which was statistically significant at 1% level of significance.

6.3. Analysis of total cost
Apple, being a perennial crop, the total cost of production was worked out by summation of amortized cost, the rental value of land, and variable cost (Table 4 and 5). The total cost of production in the HDP system (INR 932,299.74) was higher than in the conventional system (INR 48,776.28) which was statistically significant at 1% level of significance.
### Table 4. Comparison of establishment cost and total cost between HDP and conventional plantation system

| Variable                  | HDP practitioners (n = 40) | Conventional practitioners (n = 65) | Mean difference | t-value  | P-value |
|---------------------------|----------------------------|-----------------------------------|-----------------|---------|---------|
| Clearing plantation area  | 73,424.46 (25,649.88)      | 39,705.26 (3051.86)               | 33,719.19***    | 10.510  | 0.000   |
| Pit Digging Cost          | 118,478.36 (29,553.39)     | 63,608.60 (4348.78)               | 54,869.76***    | 14.754  | 0.000   |
| Planting Saplings cost    | 66,520.33 (27,300.10)      | 16,466.53 (1262.53)               | 50,053.79***    | 14.801  | 0.000   |
| Planting material Cost    | 1,949,435.54 (509,854.39)  | 28,176.18 (7760.44)               | 1,921,259.36*** | 30.467  | 0.000   |
| Fencing Cost              | 484,595.29 (127,712.85)    | 319,349.58 (25,140.11)            | 165,245.71***   | 10.146  | 0.000   |
| Total Establishment Cost  | 3,839,322.306 (777,243.618)| 467,306.17 (30,997.69)            | 3,372,016.13*** | 35.038  | 0.000   |
| Amortized cost            | 484,967.02 (98,178.14)     | 58,010.42 (3847.98)               | 426,956.60***   | 35.124  | 0.000   |
| Total Cost                | 932,299.74 (140,729.69)    | 487,776.28 (78,063.57)            | 444,523.46***   | 20.822  | 0.000   |

Notes: Figures in the parentheses indicate the standard deviation. *** represent statistically significant difference at 1% level of significance. Cost in INR ha⁻¹

### Table 5. Comparison of variable cost (material cost and labor cost) between HDP and conventional plantation system

| Variable                  | HDP practitioners (n = 40) | Conventional practitioners (n = 65) | Mean difference | t-value  | P-value |
|---------------------------|----------------------------|-----------------------------------|-----------------|---------|---------|
| Material Cost             |                            |                                   |                 |         |         |
| Fertilizer                | 28,238.99 (12,184.77)      | 3698.59 (1882.35)                 | 26,356.63***    | 16.303  | 0.000   |
| Manure                    | 80,904.92 (21,269.16)      | 71,602.52 (31,668.76)             | 9302.40         | 1.64    | 0.104   |
| Plant Protection Chemicals| 23,960.926 (10,613.12)     | 22,984.82 (3694.50)               | 976.09          | 0.679   | 0.498   |
| Labor Cost                |                            |                                   |                 |         |         |
| Manuring                  | 25,076.81 (10,637.42)      | 27,702.62 (4914.81)               | −2625.809*      | −1.718  | 0.089   |
| Spraying                  | 14,679.77 (7150.21)        | 17,003.32 (2484.18)               | −2323.54**      | −2.401  | 0.018   |
| Irrigation                | 7735.00 (3195.17)          | 11,900.00 (31,668.76)             | −4165.00***     | −10.541 | 0.000   |
| Weeding                   | 31,667.02 (12,124.21)      | 41,396.48 (7099.71)               | −9729.45***     | −5.191  | 0.000   |
| Training Pruning          | 21,665.26 (9759.36)        | 36,953.02 (35,786.69)             | −15,296.75***   | −2.639  | 0.010   |
| Harvesting                | 44,325.55 (24,394.77)      | 22,297.39 (3803.03)               | 22,028.16***    | 7.161   | 0.000   |
| Packaging                 | 16,871.80 (12,567.73)      | 9053.92 (1577.56)                 | 7817.87***      | 4.967   | 0.000   |

(Continued)
Table 5. (Continued)

| Variable               | HDP practitioners (n = 40) | Conventional practitioners (n = 65) | Mean difference | t-value | P-value |
|------------------------|----------------------------|------------------------------------|------------------|---------|---------|
| Total labor Cost       | 151,461.51 (66,617.81)     | 166,231.06 (41,483.49)             | -14,769.55       | -1.402  | 0.164   |
| Total variable cost    | 284,566.35 (92,800.231)    | 262,700.77 (54,865.080)            | 21,865.585       | 1.519   | 0.132   |

Notes: Figure in the parentheses indicates standard deviation. *** indicates statistically significant at 1%. **indicates statistically significant at 5%. *indicates statistically significant 10% level of significance.

6.4. Gross margin analysis

Apple productivity in HDP system was higher (8267.77 kg/ha) than in conventional system (8087.03 kg/ha). However, the gross margin in conventional system (INR 546,002.33) was higher than in HDP system (INR 542,211.34). This is due to an insignificant difference in variable cost between the two cultivation system and slightly higher productivity in conventional system. Here, it is to be noted that productivity is at par with one another, even though the HDP being in the juvenile phase and conventional in the full maturity phase. So, the productivity and gross margin of HDP system can be expected to increase when it transitions from the juvenile phase to full production phase in a few years thence-after making it more profitable (Table 6).

Table 6. Comparison of gross margin between HDP and conventional plantation system

| Variables     | HDP practitioners (n = 40) | Conventional practitioners (n = 65) | Mean difference | t-value | P-value |
|---------------|-----------------------------|------------------------------------|------------------|---------|---------|
| Productivity  | 8267.77 (5317.07)           | 8087.03 (2364.40)                  | 180.74           | 0.239   | 0.812   |
| Gross margin  | 542,211.34 (493,522.64)     | 546,002.33 (214,406.45)            | -3790.98         | -0.54   | 0.964   |

Notes: Figures in the parentheses indicate the standard deviation. *** represent statistically significant difference at 1% level of significance. Productivity in kg ha⁻¹, Gross margin in INR ha⁻¹

6.5. Benefit-cost ratio comparison of HDP and conventional plantation system

The benefit-cost ratio (BCR) has been calculated for 3 years starting from 2017 to 2019 ADin addition to the average BCR of these 3 years (Table 7). The BCRs of the conventional system are higher in all these years, 1.60, 1.68, and 1.72 than 0.35, 0.80, and 1.39 of the HDP system in 2017, 2018, and 2019 respectively. On average, the BCR average of three years of HDP system (0.87) is lower than that of the conventional system (1.65). All these variables were significant at 1% level of significance. According to a study conducted by Gangwar et al. (2008), the B:C ratio was worked out to be 1.28 in peach by amortization method, while it was 1.4 by investment appraisal method, and peach were at a different stage (some in the production phase and some in vegetative phase). The B:C ratio of apple was worked out to be 2.78 by Atreya and Kafle (2018) in their analysis conducted in Jumla which was based on information of 10 farmers only.

In addition, even if the HDP system is in the initial phase of establishment, the increasing trend and BCR greater than 1 in 3rd year shows the viability of this system and can be expected to benefit farmers greatly owing to its greater yield potential per unit of land.
Table 7. Benefit-cost ratio comparison of HDP and conventional plantation system

| Variables               | HDP practitioners (n = 40) | Conventional Practitioners (n = 65) | Mean difference | t-value | P-value |
|-------------------------|-----------------------------|------------------------------------|-----------------|---------|---------|
| B:C ratio (2017)        | 0.35(0.4369)                | 1.60(0.393)                        | -1.25505***     | -15.207| 0.000   |
| B:C ratio (2018)        | 0.808(0.601)                | 1.689(0.410)                       | -0.88131***     | -8.169 | 0.000   |
| B:C ratio (2019)        | 1.391(0.739)                | 1.726(0.431)                       | -0.334554***    | -2.931 | 0.000   |
| B:C ratio (Average)     | 0.877(0.5620)               | 1.654(0.3525)                      | -0.77727***     | -8.717 | 0.000   |

Notes: Figures in the parentheses indicates standard deviation. *** represents the statistically significant difference at 1% level of significance.

6.6. Production problems

Problem ranking was done by the importance of scale technique. The overall scenario of problems faced by the apple cultivators in HDP and conventional production system revealed insect pest infestation, unavailability of saplings and fertilizers, difficulties in transportation, difficulties in training pruning, and lack of postharvest storage as major problems (Table 8). For HDP practitioners, the unavailability of saplings and fertilizers was a top-ranked problem. Transportation difficulties were ranked second, lack of postharvest storage was ranked third, insect pest infestation was ranked fourth and difficulties in training pruning were ranked fifth. Similarly, for conventional practitioners, lack of postharvest storage was ranked first, followed by difficulties in training pruning, difficulties in transportation, insect pest infestation, and unavailability of saplings and fertilizers.

Table 8. Problems faced by apple growers in the study area

| Problems                                      | HDP System | Conventional System |
|-----------------------------------------------|------------|---------------------|
|                                               | Index      | Rank                |
| Insect Pest Infestation                       | 0.470      | 4                   |
| Unavailability of Saplings and Fertilizers    | 0.790      | 1                   |
| Difficulties in Transportation                | 0.657      | 2                   |
| Difficulties in Training Pruning              | 0.357      | 5                   |
| Lack of Post Harvest Storage                  | 0.537      | 3                   |
|                                               |            |                     |
|                                               | Index      | Rank                |
| Insect Pest Infestation                       | 0.575      | 4                   |
| Unavailability of Saplings and Fertilizers    | 0.455      | 5                   |
| Difficulties in Transportation                | 0.578      | 3                   |
| Difficulties in Training Pruning              | 0.692      | 2                   |
| Lack of Post Harvest Storage                  | 0.766      | 1                   |

7. Conclusion

Drip irrigation system, regular training pruning, thinning, low weeding frequency and chemical source of nutrient management were found to be some distinguishing managerial practices in the high-density plantation system. Pit manuring, flooding irrigation, intercropping, high weeding frequency were found to be more common in the conventional system. Similarly, unavailability of saplings and fertilizers and lack of post-harvest storage were major problems reported by high-density practitioners and conventional practitioners respectively. Therefore, it can be implied that if breeding and cloning of M9 rootstock or dwarfing rootstocks and scion could be done in the country, the cost of production can be greatly reduced. Also, farmers could be better benefited if provision of post-harvest storage facilities is extended and expanded. In economic analysis, the BCR of the conventional system shows that the conventional system is still profitable however, profitability per unit of land can be low. The evident increasing trend of benefit-cost ratio in the high-density plantation system, even when plants in the high-density plantation are in the initial
establishment phase can be expected to be more profitable than conventional system when all plants reach the full production phase. Even though the high-density cultivation of apples requires high investment during establishment, farmers should be encouraged to adopt this economically viable system as it can be practiced in scattered land and within the existing non-reclaimed conventional orchards, and good profit can be secured with efficient managerial practices. Moreover, further research about economics of High-Density Plantation in Apple when plants reach full production potential is required.

Acknowledgements
We would like to acknowledge Agriculture and Forestry University, Rampur, Nepal for funding the study. Also, we are thankful to Mr. Madhav Prasad Lamso (Senior Agriculture Officer-Mustang), site supervisor and Mr. Narayan Kafle (Senior Agriculture Officer-Gulmi), member-advisor for their valuable guidance.

Funding
The authors received no direct funding for this research.

Author details
Rojina Kafle1
E-mail: rojinakafle11@gmail.com
ORCID ID: http://orcid.org/0000-0002-5249-6162
Shailesh Pandit2
Rakshya Aryal1
Ankit Pokhrel1
Pratibha Bist3
Ram Hari Timilsina2
1 Department of Agriculture, Agriculture and Forestry University, Rampur, Nepal.
2 Department of Agriculture Extension and Rural Sociology, Agriculture and Forestry University, Rampur, Nepal.
3 Data availability statement

The data that support the findings of this study are openly available in figshare at https://figshare.com/articles/thesis/Data_and_tables_of_research_in_high-density_apple/15489413

Disclosure statement
The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Cover Image
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Citation information
Cite this article as: Comparing high-density plantation (HDP) system and the conventional plantation system of apple cultivation in Mustang and Manang districts of Nepal, Rojina Kafle, Shailesh Pandit, Rakshya Aryal, Ankit, Pokhrel, Pratibha Bist & Ram Hari Timilsina, Cogent Food & Agriculture (2021), 7: 1896118.

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