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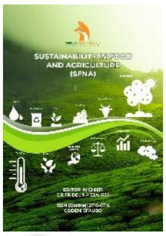

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RESEARCH ARTICLE

EVALUATION OF MANUAL FRUIT HARVESTERS AND STORABILITY CHARACTERISTICS OF HARVESTED SWEET ORANGE UNDER ORDINARY ROOM STORAGE CONDITION

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ABSTRACT

Harvesting is considered as one of the crucial and critical activities in fruit production, handling and storage and market cycle. Traditional harvesting and post-harvest technique are responsible for deteriorating the fruit quality and shortening the postharvest shelf-life. Hand-picking by climbing tree, tree shaking and stick biting are most common practices for majority of the fruit orchards in Nepal that is risky, labour and time-intensive practices as well as affects market quality and nutritive value of the fruits. Therefore, there is a need for simple manual fruit harvesting tools suitable for smallholder farmers to replace the manual picking of citrus. Hence, a study was conducted to evaluate the performance of different available models of manual fruit harvester along with the evaluation of post-harvest quality (physiological loss of weight, fruit firmness, total soluble solids, acidity and rot incidence) and shelf-life assessment of those harvested fruits during storage under ordinary room condition for 26 days. Nine harvesting treatments were investigated as follows: a) Farmer practice-hand-picking (FP_{ground}), b) Farmer practice tree climbing (FP_{climb}), c) Hand-shaking of the tree branch (TS), d) Secateurs (SE_{ground}), e) Secateur + tree climb (SE_{Climb}), f) Pole mounted cut and hold type picking shears (CH), g) Telescopic Long reach fruit picker (LRF), h) Fruit picker harvester with basket and cushion (PHB), i) Metal fruit picker with cotton bag (PC). The harvesting capacity of FP_{ground}, FP_{climb}, SE_{ground}, SE_{Climb}, LRF, CH, PHB, PC and TS methods were 98.4±5.84, 57.52±12.43, 94.7±38.14, 49.05±5.73, 79.14±6.15, 75.08±12.44, 49.88±17.48, 52.27±11.47 and 63.12±22.27 kg/hr, respectively.. The harvesting output of CH and LRF type harvester was 29.03 (591 nos/hr) and 15.93% (531 nos/hr) higher than FP_{climb} practice (458 nos/hr) and that of PHB and PC method was 20.96 (362 nos/hr) and 6.11% (430 nos/hr) lower than FP_{climb}. Regarding storability characteristics, shelf-life was found better in SE_{ground}, SE_{Climb}, CH, LRF than TS and FP practices.SE and CH method found effective in prolonging the average shelf-life and maintaining the quality of sweet orange compared to TS and FP. The button or calyx on the harvested fruit in SE, CH and LRF method help to control and delay the sap oozing, physiological loss of weight and lateral infection that maintain fruit firmness, prolong the shelf-life and minimize the fruit damage and rot incidence during ordinary storage. Based on our findings, hand-held secateur, cut and hold type harvester and long reach fruit picker (twist and turn) are recommended as appropriate harvesting tools for sweet orange fruit picking.

KEYWORDS

Hand picking, manual fruit harvesters, performance evaluation, post-harvest qualities, shaking, sweet orange

1. INTRODUCTION

Citrus fruit is one of the important cash crops for the hill farmers of Nepal in terms of area coverage, production and export potential. Sweet orange (*Citrus sinensis*; particularly named as *Junar* in Nepali), is a highly commercialized fruit among the fruit crops that are widely grown in the hills of Nepal. The contribution of the horticulture commodities amounts to 15% of agriculture GDP, of which fruits contributes 7.04 % (Panta and Dhakal, 2019; Atreya and Manandhar, 2016). In Nepal, the total fruit productive area, production and productivity in the FY 2018/19 were 120,023 ha, 1177640 mt and 9.81 mt/ha, respectively (MoALD, 2020). Citrus fruits have a total productive area of 28406 ha with 9.57 mt/ha productivity and 271908 mt production out of which sweet orange contributing to productive area of 4031 ha with 10.68 mt/ha productivity and 43061mt production during 2018/19 (MoALD, 2020). Citrus farming in mid-hill region is becoming an attractive business proposition due to unique favorable topography and agro-climatic condition and demand in the national and international market.

Postharvest losses of fruits are major problems in most of the developing countries like Nepal which mostly ranged from 20-35% as a result of inappropriate harvesting, handling and marketing practices (Rokaya et al.,

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2016; Bhattarai et al., 2013; Bhattarai, 2018). A study by Bhattarai et al. (2013) showed that the losses during harvesting, transportation, grading, packaging and marketing were 7-15, 25, 3, 1 and 5%, respectively (Bhattarai et al., 2013). Likewise, losses during post-harvest storage of citrus ranged from 15-20% (Bhattarai, 2018). Reduction of postharvest losses and quality deterioration, an increase of shelf-life are crucial for increasing food availability from the current productions and ensuring future global foods security (Kasso and Bekele, 2016). The possible causes of harvest and post-harvest losses were improper harvesting method, handling, packaging, storage, harvesting at an immature stage and microbial spoilage in injured fruit. For instance, the nature of losses by improper harvesting (up to 7% losses) of citrus includes bruises, wound, softness, puncture of fruits, physical damage, cuts, over ripen, immature, scratches, and insect infestation (Bhattarai et al., 2013). The postharvest losses can be minimized by prolonging shelf-life through using proper harvesting techniques, checking the rate of transpiration, respiration, microbial infection & protecting membranes from disorganization (Joshi et al., 2020).

Harvesting is considered as one of the crucial and critical tasks in fruit production due to possible damage to the fruits and musculo skeletal stress on the worker (Rokaya et al., 2020; Sabale et al., 2017; Li et al., 2011). At present, fruits harvesting work by farmers is performed by conventional methods such as hand-picking, tree shaking, hitting by sticks and by climbing on a tree or ladder. The use of bag and ladder is the most widely used method of harvesting citrus fruits. These practices are slow, tedious, drudgerious, labor-intensive and time-consuming methods as these requires higher energy to pick fruit and must be done by bending or sitting or climbing ladder/tree. Besides this, a person may suffer stiff shoulder, pain in the neck, knee joints and backbone and weakness after picking more fruits in a day. Moreover, there are concerns over the safety of the labourers who do harvesting work. There is a higher risk of physical injuries or even occurrence of death when a person falls from the ladder or tree during fruit picking. Importantly, those methods also deteriorate the quality and shelf-life of the fruit that will reduce earning of farmers. For instance, a study showed that a pulling method can rupture the peel off loose skin resulting in spoilage and harvesting by using clippers found effective to enhance the shelf-life (Rokaya et al., 2020).

Mechanized harvesting is recognized as the most promising area of intervention to tackle increasing phenomena of labour scarcity and costs and to fuel farm prosperity and entrepreneurial opportunity in the rural part of the country (Rickman et al., 2013). Currently, there is a dearth of research information on fruit harvesting mechanization options for smallholder farmer especially in the area of manual harvesting tools that has an immense potentiality to raise the quality citrus production and productivity. Thus, appropriate and effective small scale harvesting tools addressing those issues is a prime need of Nepalese orchards farmers and entrepreneurs. To address this gap, this study evaluated different models of fruit harvester (nine harvesting treatments) in terms of harvesting output and operational features, feedback and limitation in sweet orange harvesting. We also evaluated post-harvest quality (total soluble solids, titratable acidity, physiological weight loss, fruit firmness, and rot incidence) and shelf-life assessment of the harvested sweet orange during storage under ordinary room condition. Finally, the study will identify and recommend appropriate fruit harvester based on ease of harvester handling, harvesting output, damage to fruit and post-harvest quality. The study finding will explore the opportunities of harvesting tool on citrus harvesting for the benefit of the large number of small farmers and entrepreneurs.

2. Materials and Methods

2.1 Experimental site description

Field experimental work was performed in the farmer's citrus field of Ratnachura, Golanjar Rural Municipality, Sindhuli during the month of December 2021. Harvested sweet orange shelf-life storage trials and rest of work was performed in National Agricultural Engineering Research Centre (NAERC), NARC, Khumaltar, Lalitpur. Geographically, Ratnachura, Sindhuli is located in the central region, Bagmati Province of Nepal having latitude, longitude and average mean sea level of 27°16'N, 85°59' E and 1200 masl., respectively (Budathoki et al., 2004). It is 129 km far from Kathmandu, the capital city of Nepal. Sindhuli is the number one sweet orange production district of the country. Hilly part of Sindhuli (800-1400 masl elevation) is considered as a hub for sweet orange (*Junar*) farming due to favorable climate for sweet orange. During 2018/19, Sindhuli occupied a sweet orange productive area of 725 ha with 12.25 mt/ha productivity and 8881 mt productions (MoALD, 2020).

2.2 Features of manual fruit harvester used in this study

The general characteristics of different model of fruit harvester used for sweet orange harvesting in our study were presented in Table 1 and Figure 2. The experimental treatments were a) Farmer practice-hand-picking (FP_{ground}), b) Farmer practice tree climbing (FP_{climb}), c) Hand-shaking of the tree branch (TS), d) Secateurs (SE_{ground}), e) Secateur + tree climb (SE_{Climb}), f) Pole mounted cut and hold type picking shears (CH), g) Telescopic long reach fruit picker (LRF), h) Fruit picker harvester with basket and cushion (PHB), i) Metal fruit picker with cotton bag (PC). Treatment no. (d) to (i) are the manual fruit harvesting tools used in this study.

Table 1: Features of manual fruit harvesters used in this study.

Treatment	Harvesting method*	Features and operation
1	FP_{ground}	Farmers hand-picking method for fruit reachable from the ground, pulling.
2	FP_{climb}	Farmers hand-picking method, fruit unreachable from the ground, pulling by climbing tree.
3	Tree shaking	Shaking of Individual stem having fruits.
4	SE_{ground}	Use of handheld Secateur for fruit reachable from the ground
5	SE_{climb}	Handheld Secateur plus climbing tree for fruit unreachable from the ground.
6	CH	It can cut and hold the pedicle of fruits until the handle is released. It will be easy to harvest fruit or prune stem unreachable from ground without touching by hand or using a ladder. The ergonomic spring-loaded handle will spring back to allow another cut and help reduce hand and wrist fatigue. Due to the sharp pruner blade, need to be careful when cleaning and need to put it in a locked position at the time of unused condition.
7	LRF	Twist, and turn the fruit and then hold the fruit inside the fingers of the picker. Allow easily pick and reach fruit which is unreachable from ground. Three soft rubber padded claws keep each piece of fruit safe from damage. Hold fruit from 5.5 to 13 cm in diameter. Adjustable pole ranging from 1m to 2m.
8	PHB	The fruit stem of the fruit which needs to be picked is line up in between two of the long prongs and then gently pull down so that fruit will fall in picker basket. The fruit picker basket can hold multiple pieces of fruit, so that there's no need to retract the basket after each pick. The basket is 15cm wide and 33 cm high.
9	PC	It consists of a metal fruit picker head having a diameter: 14cm and bag depth: 25cm. The teeth of the ring cut fruit by pulling action and fall inside a cotton bag and later gather them in the fruit picker bag. The fruit picker bag can hold multiple pieces of fruit so that there's no need to retract the basket after each pick.

*Farmer practice (FP_{ground}), Farmer practice tree climbing (FP_{climb}), Hand shaking of the tree branch (TS), secateurs (SE_{ground}), Secateur +tree climb (SE_{Climb}), Pole mounted cut and hold type picking shears (CH), Telescopic Long reach fruit picker (LRF), Fruit Picker harvester with basket and cushion (PHB), Metal fruit picker with cotton bag (PC). Treatment no. 4 to 9 are the manual fruit harvesting tool used in this study.

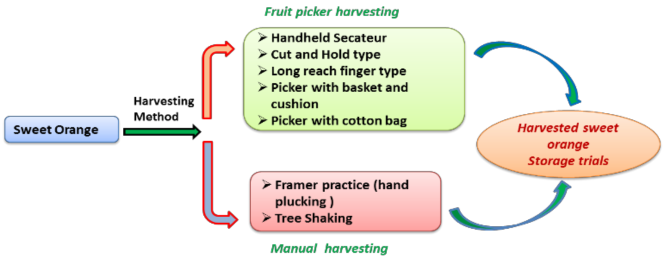

Figure 1: Schematic diagram of experimental set up in this study

A) Farmer practice-hand picking (FP_{ground}), B) Farmer practice tree climbing (FP_{climb}), C) Secateurs (SE_{ground}), D) Secateur +tree climb (SE_{Climb}), E) Pole mounted cut and hold type picking shears (CH), F) Telescopic long reach fruit picker (LRF), G) Fruit picker harvester with basket and cushion (PHB), H) Metal fruit picker with cotton bag (PC), I) Hand shaking of the tree branch (TS).

Figure 2: Photographic view of harvesting experiment on sweet orange in farmer's field

2.3 Experimental methodology, data collection and Statistical analysis

A schematic view of the experimental set-up designed for this study is shown in Figure 1. Five sweet orange trees (code1-5) were selected and marked with the code number for identification. The tree profile of each selected tree was recorded and presented in Table 2. Both manual picking and harvester picking of sweet orange was performed systematically. Figure 2 shows the photographic view of harvesting experiments conducted in the farmer's field. Harvested sweet orange (kg) was recorded using an electronic weighing balance. Likewise, harvesting time (min) was noted by using stopwatch. Harvested samples from manual picking (farmers practice) and manual fruit harvesters are collected carefully in a crate for storage trials. Feedback on harvester from the farmers was noted down. All experiments were done in triplicate. The harvesters were evaluated based on harvesting capacity, damage number of fruits and feedback from farmers and fruit quality assessment of the harvested fruit by conducting storage trials.

Storage trial was conducted in NAERC, Khumaltar, Lalitpur at room temperature in a well-ventilated room from December 21, 2021, to January 15, 2021 (26 days). Vernier calliper (accuracy of 0.01 mm) is used to measure the linear dimensions of sweet orange (length, major diameter and minor diameter in cm) along three perpendicular axes. Five fruits for each replication of each treatment were coded and used for determining physiological loss in weight (PLW), rot incidence or damage, shrinkage and shelf-life during ordinary storage condition. The weight of samples was taken by using digital balance from the first day (day 1) till the samples were rejected at the interval of 1 day. Observations on PLW, shrinkage behavior and damage due to rotting were noted. The numbers of the rotted samples were noted each day. PLW (%) was obtained from the weight loss during storage and initial values as per following equation 1

$$PLW\ (\%) = \frac{WI-WF}{WI} * 100 \tag{1}$$

Where,

PLW: physiological weight loss (%)
WI: Initial weight at the start of storage (day first) in g
WF: Weight measured at the certain day interval of storage duration in g.

Likewise, ten samples for each treatment were allocated for quality assessment of the harvested fruit. Physicochemical quality parameters such as shrinkage, fruit firmness, total soluble solids (TSS), titratable acidity (TA) and TSS/TA ratio were analyzed on day 1, day 11, day 17 and day 26 of storage. Fruit firmness (kg/cm^2) was measured by a handheld digital fruit hardness tester (Lutron FR-5120) using 11mm penetrometer tip. Briefly, three points per fruit were selected for puncture. The fruit is held against a hard surface and force is gently applied at a slow and uniform speed to make a puncture in the fruit with the selected tip. Each firmness value was an average of the three puncture point values. TSS (^{o}Brix) was measured directly using a handheld refractometer (ATAGO N1 Brix 0-32%, Japan).

TA was determined by titrating aqueous solution (filtrate) of sweet orange juice with 0.1N standard NaOH using phenolphthalein indicator and expressed as a percentage of citric acid (AOAC, 2005). TSS /TA ratio was calculated by dividing the TSS content by TA of each treatment. Damage number due to rot (cumulative decay loss) and the color change was determined by visual observations. Shelf-life was determined based on observation of color, brown patches on outer cover and rot incidence of fruit. Dry bulb temperature and wet bulb temperature were taken daily at 6:00 AM, 10:00 AM, 1.30 PM, 5:00 PM and 9:00 PM and was averaged for the daily temperature. The recorded temperature values were also used to calculate relative humidity. Descriptive analysis was done to summarize data into averages and standard deviations values by the statistical tool using MS Excel.

3. Results and Discussion

3.1 Temperature and relative humidity of the storage site during experiment period

The weather was winter during the experimental period in Lalitpur. Temperatures and relative humidity (RH) were higher than the ideal requirement of citrus storage. For citrus storage, ideal room temperatures and RH should be between 3-9^{0}C and 85-90% which can have a storage life up to 8 weeks (Liu 2010, FAO 2020). The average daily outside dry temperature was 13.94^{0}C (average of 26 days average reading, n=26) which varies from 0 to 28.5^{0}C within a day while that of storage room was 11.84^{o}C which ranged from 9^{0}C to 16^{0}C during the experimental storage period (Table 2a). Likewise, the average daily RH of storage room was 63.78% which ranged from 41.8% to 77.9% while that of the outside was 66.82% which ranged from 29.2% to 100%. Furthermore, the average temperature and RH variation within a day was obtained from the values of 6:00 AM, 10:00 AM, 1.30 PM, 5:00 PM and 9:00 PM for up to 26 days and shown in Table 2b. From Table 2b, it can be seen that room temperature increased from 10.5^{o}C at 6 AM to 13.4^{o}C at 5 PM and then decreased at 9 pm (11.8^{0}C). Similarly, RH is high at 10:00 AM (68.5%) and 9:00 PM (68.3%) and lowest value (54.8%) at 1.30 PM.

Table 2a: Temperature and relative humidity of experimental period

	Average daily temp (°C)		Average relative humidity (%)	
Storage duration	Outside	Inside room	Outside	Inside room
Day 1-Day7	13.29±0.9	11.67±0.35	70.73±6.76	62.99±2.44
Day 8-Day 14	13.02±1.58	10.64±0.42	63.61±4.10	61.50±1.74
Day15-Day21	15.93±1.22	12.90±0.57	60.27±7.84	63.32±6.66
Day22-Day26	13.54±1.0	12.14±1.0	72.65±3.88	67.33±0.53

Table 2b: Average temperature and relative humidity in a day at certain hour interval

Parameters/ time		6:00 AM	10:00 AM	1.30 PM	5:00 PM	9:00 PM
Avg. dry temp (°C)	outside	3.3± 2.8	19.3± 2.8	23.5± 3.3	14.9± 1.8	8.3±2.7
	storage room	10.5 ±1.1	11.0± 1.1	13.0± 1.4	13.4± 1.1	11.8± 1.3
Avg. relative humidity (%)	outside	85.6 ±4.3	56.7± 13.2	47.7± 12.7	60.5± 12.6	81.3± 10.2
	storage room	68.01±4	68.5± 4.0	54.8± 7.9	58.0± 7.4	68.3± 5.9

N=26

3.2 Tree canopy profile and physical properties of harvested sweet orange

Table 3 summarizes the profile of citrus trees that were used in this experiment. From Table 3, it can be seen that the citrus tree is about 14 years old and the spacing between the two trees is 4- 5m. The height and canopy diameter of a tree is 4 to 8 m and 3 to 5 m, respectively. The minimum height of location of fruit from the ground is 2m and maximum height of that is 7m. Most of the fruit (72-81.7%) located around the outer periphery/circumference of citrus canopy height unreachable from ground. Thus, considering farmer's conventional practice, harvesting needs either use of a ladder or tree shaking/climbing. Likewise, the mean, standard deviation, maximum-minimum values of linear dimension (major diameter, minor diameter and length) and mass of harvested sweet orange that were evaluated in this study are summarized in Table 4. From the table, considering overall treatments, it can be seen that maximum-minimum values of length, major diameter and minor diameter of the harvested sweet orange were 7.49-5.45, 7.68-5.70 and 7.50-5.50 cm, respectively. Similarly, maximum-minimum values of mass for harvested fruit ranged from 211-99 g.

Table 3: Experimental tree profile

S.N	Parameters/Tree code no.	1	2	3	4	5
1	Height of tree (m)	6	5.5	4	6	6
2	Diameter of tree canopy(m)	5	6	3	3	4
	Location of fruit from the ground (m)					
3	a) Maximum	6	5	4	6	5.5
	b) Minimum	2	2	2	2	2
4	Colour and condition of fruit	Matured yellow color				
5	No of fruits around the periphery of tree height reachable from ground(nos.)	300	270	150	270	350
6	No of fruits around the periphery of tree height unreachable from ground (nos.)	900 (75%)	850 (75.8%)	670 (81.7%)	800 (74.7%)	900 (72%)
7	Spacing between tree (m)	4-5				
8	Tree age (year)	14				

Table 4: Physical characteristics of harvested sweet orange

Harvesting methods	Descriptive statistics	Length (cm)	Major Dia (cm)	Minor Dia. (cm)	Weight (g)
FP_{ground}	average	6.27±0.40	6.90±0.39	6.80±0.36	154.2±24.77
	max-min	7.49-5.60	7.68-6.39	7.50-6.25	211.0-120.0
FP_{climb}	average	6.09±0.11	6.54±0.19	6.48±0.20	137.2±10.30
	max-min	6.28-5.85	6.90-6.25	6.79-6.06	156.0-121.0
SE_{ground}	average	6.22±0.47	6.64±0.34	6.62±0.39	143.07±23.60
	max-min	7.28-5.6	7.41-6.2	7.35-6.1	190-116
SE_{climb}	average	6.19±0.32	6.48±0.29	6.40±0.28	134.1±17.91
	max-min	6.75-5.72	6.85-5.95	6.8-5.95	160-106
CH	average	6.31±0.30	6.64±0.29	6.53±0.30	144±17.18
	max-min	6.9-5.95	7.26-6.05	7.25-6	184-112
PHB	average	6.23±0.30	6.77±0.33	6.65±0.34	147.2±20.64
	max-min	6.65-5.65	7.28-6.3	7.19-6.15	184-118
LRF	average	6.37±0.30	6.70±0.35	6.65±0.31	148.53±20.10
	max-min	6.8-5.75	7.15-5.91	7.01-5.91	177-106
PC	average	5.98±0.38	6.38±0.31	6.31±0.33	125.8±18.13
	max-min	6.48-5.45	6.8-5.88	6.75-5.8	150-99
TS	average	6.16±0.32	6.45±0.38	6.37±0.40	133.27±22.10
	max-min	6.65-5.55	7.00-5.70	6.9-5.50	172.0-99.0

N=15 for each treatment.

3.3 Performance evaluation of different models of fruit harvester

Harvesting output of different treatments was evaluated based on kg per hour and the number of fruit per hour and summarized in Table 5. The harvesting capacity of citrus differed significantly with different harvesting treatment. Based on a weight basis, the harvesting capacity was found to be higher with FP_{ground} (98.4±5.84 kg/hr) followed by SE_{ground} (94.7±38.14 kg/hr). The higher value of harvesting output in FP_{ground} and SEground treatment can be due to the easy accessibility of fruits to the person staying on the ground. The lowest harvesting capacity was obtained with SE_{climb} (49.05±5.73 kg/hr) and PHB (49.88±17.48 kg/hr). The reason can be due to the operation of secateurs in climb position for SE_{climb} treatment and hook and pull method in PHB treatment. From Table 5, it can be seen that CH, LRF, PHB and PC method can harvest 591,531, 362 and 430 sweet oranges per hour, respectively.

The harvesting output of SE_{climb}, CH and LRF type harvester was 1.5%, 29.03% and 15.93% higher than FP_{climb} practice and that of PHB and PC method was 20.96% and 6.11% lower than FP_{climb}. Fruits can be easily picked by the use of CH, LRF, PHB and PC type fruit harvester when the fruit is difficult to reach from ground. The operation was very convenient after being familiar with harvester and fruit could be easily harvested up to a height of 3.3m, 2.5m, 3.9-4.9m and 2.1m from the ground in LRF, CH, PHB and PC model fruit harvester, respectively. The harvesting output depends on the yield of fruits per tree, knowledge and skill on handling and operational methodology of manual fruit harvester and familiarity with the use of fruit harvester.

The shaking method has a capacity of 592 numbers of citrus per hour. The major disadvantage of this method is the higher damage of sweet orange because of the free falling of fruit directly on the ground. Shaking also resulted in falling of unripe fruit which is not yet in a harvesting stage and will increase bruising and mechanical damage. Likewise, PHB type and PC type harvester harvest the fruit by hooking and pulling which caused the peeling of the outer soft skin of fruits like orange. Pulling the fruit usually causes the button to be removed and even breaks the skin at the stem end (Bentil et al., 2020). Based on harvesting performance and farmers response, Secateur (SE), cut and hold (CH) and long reach fruit picker type (LRF) harvesters are the suggested models of fruit harvester for sweet orange harvesting.

Table 5: Harvesting output of farmers practice and manual fruit harvesters

Parameter	H.M. Unit	FP_{ground}	FP_{climb}	SE_{ground}	SE_{climb}	LRF	CH	PHB	PC	TS
Harvesting output	kg/hr	98.4±5.84	57.52±12.43	94.7±38.14	49.05±5.73	79.14±6.15	75.08±12.44	49.88±17.48	52.27±11.47	63.12±22.27
	Number/ hour	680±45.82	458.2*±80.44	650±141.77	465±21.21	531.36±60.01	591.64±63.49	362.14±152.14	430.5±94.5	592±81.19
Difference in harvesting output (%)					1.5	15.93	29.03	-20.96	-6.11	29.25

*Represents harvesting output of farmer practice (FPclimb) from which the percentage difference for the other treatment was calculated. All values are expressed as means ± standard deviation (n= 3).

3.4 Effect of harvesting methods on the fruit quality under ordinary storage condition

The fruit quality (PLW, rot incidence, color, fruit firmness, TSS and TA) of harvested sweet orange during storage condition were measured, analyzed and illustrated in this section.

3.4.1 Physiological loss in weight (PLW)

Weight loss is considered a major parameter to analyze postharvest deterioration in citrus fruit because fruits contain 65-95 percent of water. Water loss causes shrinking, desiccation, softening, wilting and influences the texture and visual appearance of the fruit. The results displayed in Table 6 shows that the initial PLW of fruit harvested by harvesters is not only lower than that of TS and FP practice but also delay in the decrease of weight than that of those practices. For instance, on day 11, the PLW in SE, CH and LRF harvested fruit were 6.56%, 6.97% and 6.83%, respectively whereas 13.14% and 9.21% were obtained for TS and FP practice. However, we found almost similar PLW (9.69% and 9%) in PHB and PC method which is almost equal to FP practice but lower than TS values. Likewise, in 17 days, the loss was the greatest (12.87%) in PHB and the least (10%) in LRF method. PLW of FP, PHB and PC lies between 12-13% however that of SE, CH and LRF ranged from 10 to 11% at that day. Importantly, in 26 days, PC had the highest (19.56%) weight loss while it was the lowest (15.97% and 16.03 %,) in LRF and SE method.

Fruit damage during harvest increased quick water loss and increased rot incidence and ethylene production rates (Bentil et al., 2020; Kitinoja and Kader, 2002; ElShiekh and AbuGoukh, 2008) leading to quick deterioration of fruit in TS (dropping of fruits), FP (pulling), PHB and PC method (hook and pull). On the contrary, minimum PLW in SE, CH and LRF method could be due to the lack of bruises and less evapotranspiration from the fruit surfaces. Previous studies on the effect of harvesting methods on the storage behavior of fruits support our findings. For instance, a recent study by Rokaya et al. (2020) evaluated mandarin storability under cellar condition and reported less water loss in clipped fruits (3.15%) than that of fruit harvested by sticks (15.81%) (Rokaya et al., 2020). As well a study, reported a weight loss of 18-21% in fruit stored at room temperature for 12 days (Purbiati and Supriyanto, 2013). In a similar study in mango, Waskar et al. (1997) reported that fruits harvested by using harvesters have weight loss of 12.3-13% as against 17.20% of manual harvesting after 16 days of storage.

Table 6: Physiological weight loss (PLW in %) of harvested sweet orange during ordinary storage

Physiological weight loss (PLW in %)												
Treatments	Days of storage											
	3	5	7	9	11	13	15	17	19	21	24	26
FP_{ground}	1.94±0.37	4.23±0.43	5.98±0.37	7.52±0.53	9.21±0.71	11.27±0.60	12.62±0.82	-	-	-	-	-
FP_{climb}	2.17±0.54	4.03±0.50	5.52±0.31	6.89±0.25	8.29±0.42	10.08±0.68	11.22±0.77	-	-	-	-	-
SE_{ground}	1.52±0.21	2.88±0.23	4.89±0.03	5.89±0.15	6.85±0.18	8.92±0.14	9.93±0.09	10.93±0.10	12.28±0.26	13.98±0.14	15.81±0.22	17.88±0.70
SE_{climb}	1.48±0.54	2.99±1.14	5.08±0.85	5.737±1.59	6.56±1.66	8.23±1.17	9.49±0.84	10.25±1.46	10.98±2.03	12.71±1.48	14.48±1.83	16.03±2.33
CH	1.24±0.21	3.45±0.27	4.97±0.25	5.94±0.24	6.97±0.29	8.86±0.46	10.51±0.35	11.00±0.52	11.64±0.65	13.61±0.67	15.32±0.91	16.53±0.42
PHB	2.11±0.34	4.23±0.27	6.72±0.28	7.96±0.73	9.69±0.80	11.23±0.53	-	-	-	-	-	-
LRF	1.50±0.18	3.15±0.44	4.84±0.36	5.62±0.57	6.83±0.48	8.79±1.04	9.93±0.98	10.00±1.06	11.06±0.34	12.86±1.24	14.82±1.18	15.97±0.81
PC**	2.06±0.55	4.10±0.99	6.36±1.75	7.35±1.93	9.00±1.44	10.41±2.48	12.22±2.61	12.71±3.13**	-	-	-	-
TS	3.67±0.32	6.85±0.60	9.83±1.08	12.37±2.17	-	-	-	-	-	-	-	-

** Higher standard deviation is due to variation in weight loss in PC method where some samples have peduncle during harvesting by this method which has prolonged shelf-life than one without peduncle in this method. PLW measurement was stopped after the first rot incidence started in harvested samples.

3.4.2 Rot incidence (decay loss) and shrinkage behavior

Table 7 shows the percentage of decayed fruits which were stored for 26 days under ordinary room condition. From table 7, sweet orange harvested through shaking treatment and farmers practice (pull method) had the highest rot incidence (100%) followed by PHB (90%) and PC (70%) harvester treatment during the 26 days storage. 10% (at day 24) and no rot incidence occurred in the fruit harvested by SE and CH method, respectively. Among the treatments, the earlier physiological disorder (brown patches on the rind and fruit discolor) and decay loss (20%) started from 6 and 9 days of storage in TS method where 100% decay loss has occurred in 17 days of storage. Likewise, the decay loss (6.7%) started from 11 days and reached 93-100% on day 26 in FP practice. This could be attributed to skin fracture, damage, puncturing and injuries of fruit like bruises and other damages due to freefalling directly on the ground (shaking method) and peeling or wound of outer skin nearby peduncle extremity in farmers pull method (FP). Similarly, PHB type and PC type harvester harvest the fruit by hooking and pulling which ultimately caused peeling of the outer soft skin of a fruit.

From our daily visual observation, we found that the injured area of the damaged fruits begins to discolor with multiple brownish spots. Later softening and decay caused by molds was seen in shaking and FP practice. Decay of fresh produce during storage is mostly caused by the infection of mechanical injuries provoked by microorganisms, mostly mold, bacteria and fungi (FAO, 2020). In contrast, lower rot incidence in SE and CH treatments is attributed to intact fruit with controlled sap oozing and lateral infection due to the presence of pedicel in fruit (Singh et al., 1993; Sonkar et al., 1999; Kumargoud et al., 2017). Moreover, fruits with intact stalk were less prone to fungal infection during storage than those without fruit stalk (Rokaya et al., 2020; Purbiati and Supriyanto, 2013; Waskar et al., 1997). Likewise, twisting, turning action by the three soft rubber padded claws of LRF prevents peeling and damage of outer skin around peduncle extremity point. However, hardening of the skin and development of wrinkling/shrinkage appeared as a result of water loss in SE and CH method at day 26 of ordinary storage condition. The shrinkage of outer peel is attributed to weight loss after long term storage due to the dehydration process. Since the peel is a visible marketing feature, changes in the appearance of the peel will have an adverse effect on the marketability of the fruits.

From our achieved results of rot incidence and visual appearance of fruit (marketability), the shelf-life of TS and FP practice was 7 days and 9-13 days, respectively. Compared to the harvested fruit shelf-life, the use of harvesters in sweet orange picking prolonged shelf-life to 13 and 17 days in PC and LRF and 21 days in SE and CH method, respectively. However, PHB method has a similar value of shelf-life as that of FP. A previous study in mango reported fruits with stalk had 2–4 days more shelf-life with minimum decay loss and higher marketability (Singh et al., 1993; Waskar et al., 1997). Controlled storage condition (85-90% RH and 3-9^{0}C) are being practiced for reducing the rate of water loss, shriveling, wilting and textural changes, and further enhance the shelf-life of harvested fruit (Rokaya et al., 2020). These study findings are based on ordinary room storage condition thus further study on fruit quality of the harvested fruits on the controlled storage condition is recommended.

Table 7: Rot incidence (%) of harvested sweet orange stored for 26 days

Cumulative rot incidence (%)													
Harvesting methods	Days of storage (day)												Shelf-life (day)*
	3	5	7	9	11	13	15	17	19	21	24	26	
FP_{ground}	-	-	-	-	-	-	53.3	66.7	86.7	86.7	86.7	93.3	13
FP_{climb}	-	-	-	-	6.7	13.3	20.0	66.7	73.3	100	-	-	9
SE_{ground}	-	-	-	-	-	-	-	-	-	-	-	-	21
SE_{climb}	-	-	-	-	-	-	-	-	-	-	10	-	21
CH	-	-	-	-	-	-	-	-	-	-	-	-	21
PHB	-	-	-	-	-	-	10	10	50	70	90	-	13
LRF	-	-	-	-	-	-	-	-	6.7	-	-	-	17
PC	-	-	-	-	-	-	-	-	30	50	70	-	13
TS	-	-	-	20.0	26.7	33.3	93.3	100	-	-	-	-	7

*Shelf-life was estimated based on start of decay loss and daily visual observation of color, brown patches on outer cover and rot incidence of stored samples

3.4.3 Fruit firmness

Fruit firmness is a critical post-harvest quality parameter as consumers select a firm rather than a soft one (Mahajan et al., 2016). The firmness values of sweet orange harvested by different methods during storage were shown in Table 8. The fruit firmness of the sweet orange decreased with an increase in the storage period irrespective of the harvesting method (except SE and CH). For instance, the fruit firmness was 9.7, 10.4, 9.3 and 11.2 kg/cm^2 for TS, FP, PHB and PC method at day 1, but decreased to 5.2, 6.9, 7.5 and 7.6 kg/cm^2, respectively in 26 days (Table 8). The decline in fruit firmness was found to be abrupt and fast in TS method (9.7 on day 1 to 5.4 on day 17). On the contrary, SE and CH method harvested sweet orange has maintained fruit firmness values of day 1 (9.2 kg/cm^2) till 17 days. But we find increased values of firmness in SE (10.3), CH (11) and LRF (9.9) while the lowest was recorded in TS method (5.2 kg/cm^2) at day 26.

The decrease in fruit firmness is related to loss of pectic substances (degradation of protopectin by pectinatase) in the middle lamella of the cell wall that leads to the loss of cell wall integrity, that in turn results softening and shriveling of fruit (Faasema et al., 2011; Mahajan et al., 2016). The decrease in the firmness could also be attributed to fruit senescence due to prolonged storage in ordinary storage condition that will reduce fruit quality and poor visual appearance to consumers (Alhassan et al., 2014). In contrast, the fruit firmness consistency in SE and CH could be lesser mechanical damage that lowers the respiration rate and slowdown in PLW and breakdown of starch to glucose and fructose (Mahajan et al., 2016; Rokaya et al., 2020). But, the high value of firmness in those methods on day 26 could be due to hardening of the skin as a result of water loss and the development of wrinkling after long term storage in ordinary room condition (Faasema et al., 2011). Based on fruit firmness, we recommend 11-15 days storage under ordinary room or unmodified condition of storage for fruit harvested by manual harvester (SE, CH, and LRF).

Table 8: Fruit firmness of harvested sweet orange stored for 26 days

Fruit firmness (kg/cm^2)				
Harvesting methods	days of storage			
	day 1	day 11	day 17	day 26
FP_{ground}	10.4±0.3	8.8±0.6	7.8±0.6	6.9±0.2
FP_{climb}	9.1±0.9	8.2±1.1	7.6±0.3	6.8±0.4
SE_{ground}	9.2±0.4	9.5±0.1	9.3±0.3	10.3±0.3
SE_{climb}	8.8±0.1	9.0±0.9	9.1±0.2	10.0±0.3
CH	9.1±0.1	9.3±0.2	9.9±0.4	11.0±0.4
PHB	9.3±0.4	8.8±0.6	8.1±0.1	7.5±0.2
LRF	11.0±1.6	11.8±0.4	10.9±0.6	9.9±0.6
PC	11.2±0.5	10.9±0.4	8.5±0.9	7.6±0.4
TS	9.7±0.6	7.8±0.4	5.4±0.8	5.2±0.2

3.4.4 *Total soluble solids (TSS)*

During the storage, the TSS content had fluctuated irregularly. TSS increased with storage, regardless of the harvesting methods (Table 9). For instance, on day 1, initial TSS lie within 8.5- 10 but at the end of the storage period (day 26), TSS values lies within 10-11%. The higher value of TSS occurred in FP (11), TS (11), and PHB (12) on day 17 while that for SE (10) and CH (11) was obtained on day 26. The increase in TSS values was seen earlier in the fruit harvested by FP, TS, PHB and PC method than those by SE and CH method (Table 9). The increase in TSS could be due to hydrolysis of polysaccharides (starch, pectin and other insoluble carbohydrates) to simpler sugars like glucose and fructose (Jafarpour and Fatemi, 2012; Faasema et al., 2011; Alhassan et al., 2014; Purbiati and Supriyanto, 2013; Rokaya et al., 2020). The delayed increase in TSS of CH and SE harvested fruit might be attributed to delayed ripening, lower metabolic activities due to intact fruit rind and slower senescence processes. Consequently, the decrease in TSS is due to exhaustion of acids and the conversion of sugars to other organic products as a substrate for respiration (Faasema et al., 2011). A study reported that fruit harvested by hitting with a stick has high respiration rate and quick increase of TSS than that by clipper (Rokaya et al., 2020; Purbiati and Supriyanto, 2013). Likewise, a study found an increase in TSS during storage of grapefruits, and they attributed this to the loss in moisture content which led to the concentration of TSS (ElShiekh and AbuGoukh, 2008).

3.4.5 *Titratable Acidity (TA)*

The acidity of fruits has a decreasing trend in all groups of harvesting method with the increase of storage duration (Table 9). However, we find a slower decrease in harvester (SE and CH) harvested fruits compared to FP, and PHB and PC type harvester (Table 9). For instance, on day 1 of storage, TA of FP, TS, SE, CH, PHB, LRF and PC was 1.52, 1.38, 1.35, 1.5, 1.45, 1.41 and 1.55%, respectively. On the day 26, it was decreased to 1.01, 0.84, 1.05, 1.23, 0.85, 1.08 and 0.92% for FP, TS, SE, CH, PHB, LRF and PC, respectively. The decrease in acidity might be the postharvest metabolic activities that break down pectin substances into pectic acid during long term storage of fruits in ordinary condition (Ullah et al., 2018). In other words, the decrease in titratable acids during storage may be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits through the process of respiration (Mahajan et al., 2016). Previous studies reported that the TSS did not change much while TA dropped more in manually harvested fruit as compared to clipped fruit (Sonkar et al., 1999). There was a rapid decline of acidity in TS, FP, PHB and PC method compared to SE, CH and LRF method during storage (Table 9). The presence of peduncle in SE and CH method might have helped in better retention of acidity and delayed the post-harvest metabolic activities (respiratory and ripening process) as compared to TS practice. With the increase in storage duration, acidity was decreased but the use of proper harvesters like SE and CH reduced and delayed the postharvest decrease in the acidity of sweet orange compared to FP practice.

3.4.6 *TSS/TA*

An increase in TSS/TA ratio occurred in all the harvested sweet orange over the longer storage duration (Table 9). For example, TSS/TA ratio ranged from 5.59 to 7.09 on day 1 however, it ranged from 9.52 to 13.75 in 26 days of storage. TSS/TA ratio of SE and CH harvested sweet orange has lower values (8.94-9.52) than FP (10.89-13.75), TS (11.90), PC (11.96), and PHB (11.76) at day 26. Fruits having TSS/TA ratio higher than 19 are regarded as sweet and less acidic in taste (Mavis et al., 2014). Although the values are below 19, the increase in TSS /TA ratio could be due to a reduction in TA and an increase of TSS in our study. A high TSS/TA has generally been regarded as a quality index for orange fruits. However, the increase in TSS/TA during our storage trials can also be accompanied by the development of off-flavors due to the formation of ethanol in the fruit, an indication of spoilage which was supported by rot incidence phenomena of our study (Mavis et al., 2014; Davis et al., 1974). Thus, we recommended controlled storage condition trials for the TSS/TA phenomena.

Table 9: Total soluble solids (TSS), Titrable acidity (TA) and TSS/TA ratio of harvested sweet orange stored for 26 days

Harvesting methods	TSS (°Bx)				TA (%)				TSS/TA			
	Days of storage				Days of storage				Days of storage			
	1	11	17	26	1	11	17	26	1	11	17	26
FP_{ground}	8.5	10	11	11	1.52	1.18	1.17	1.01	5.59	8.47	9.40	10.89
FP_{climb}	9	10	10	11	1.38	1.12	1.05	0.8	6.52	8.93	9.52	13.75
SE_{ground}	9	9	9	10	1.35	1.27	1.26	1.03	6.67	7.09	7.14	9.71
SE_{climb}	8.5	9	9	10	1.56	1.54	1.08	1.05	5.45	5.84	8.33	9.52
CH	10	9	10.5	11	1.5	1.49	1.3	1.23	6.67	6.04	8.08	8.94
PHB	9	11	12	10	1.45	1.34	1.22	0.85	6.21	8.21	9.84	11.76
LRF	10	10	10.5	10.5	1.41	1.40	1.24	1.08	7.09	7.14	8.47	9.72
PC	8.8	10	10	11	1.55	1.15	1.14	0.92	5.68	8.70	8.77	11.96
TS	9	10	11	10	1.38	1.09	1.02	0.84	6.52	9.17	10.78	11.90

4. Conclusion

- Based on the number per hr, the harvesting output of SE, CH and LRF type harvester was 1.5%, 29.03% and 15.93%, higher than FP_{climb} practice and that of PHB and PC method was 20.96% and 6.11% lower than FP_{climb}.
- SE and CH method found effective in prolonging the average shelf-life and maintaining the quality of sweet orange for 21 days under ordinary room condition as opposed to 7 days and 9-13 days only in the case of TS and FP. This indicates synergistic effect of the button or calayx on maintaining the harvested fruit quality in storage condition by minimizing the fruit damage and rot incidence during ordinary storage.
- The storage trials on fruit quality showed that use of appropriate harvester delayed the decrease of PLW and TA, and also slower down TSS accumulation, resulting in improved fruit quality, reduced post-harvest losses and extended shelf-life of fruits during storage.

The manual fruit harvester is a useful tool that can be used for picking fruits without shaking branches and climbing a ladder or tree. Overall, from our findings, we suggest the use of hand-held secateur, cut and hold type harvester and long reach fruit picker (twist, turn and hold) to minimize the physical working stress of farmers in harvesting sweet orange and the fruit damage during harvest and post-harvest operation. The shaking the branch of the tree was the inappropriate harvesting method that ultimately affects the fruit quality and shelf-life. Among the different types of fruit harvester; SE, CH and LRF are appropriate harvesting tools for fruit picking. However, further investigations using controlled storage condition would be required to obtain data which could be used for stored fruit quality aspects.

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REFERENCES

Alhassan, A.F., Adjei, P., Mohammed, S., 2014. Effect of maturity stage and storage duration on physico-chemical properties of citrus (Citrus sinesis var. Late valencia). European scientific journal, 10 (36), Pp. 148-162.

AOAC. 2005. Official methods of analysis (16th edition). Association of official analytical chemists. Washington D.C. USA.

Atreya, P.N., Manandhar, R., 2016. Fruit crop development in Nepal: achievements and future strategy. Proceedings of the first International Horticulture Conference, Nepal Horticultural Society.https://www.researchgate.net/publication/326543525_fruit crop development in Nepal achievements and future_strategy (Accessed on 2020/12/10).

Bentil, O.P., Charles, A., Edmund, O., 2020. Effects of Harvesting Methods on the Quality Characteristics of Citrus Fruits in the Central Region of Ghana. Science Development, 1 (1), Pp. 1-7. doi: 10.11648/j.scidev.20200101.11.

Bhattarai, R.R., Rijal, R.K., Mishra, P., 2013. Postharvest losses in mandarin orange: A case study of Dhankuta District Nepal. African Journal of Agricultural Research, 8 (9), Pp. 763-767.

Bhattarai , D.R., 2018. Post-harvest horticulture in Nepal. Horticulture International Journal, 2 (6), Pp. 458-460. DOI: 10.15406/hij.2018.02.00096.

Budathoki, K., Regmi, H.N., Pradhan N.G., Gotame, T.P., 2004. Citrus diversity, their characterization and evaluation in Nepal. Advances of Horticulture Research in Nepal Proceeding of the Forth National Workshop on Horticulture, Pp. 116-122, Eds: B.B. Khatri, B.P. Sharma, P.P. Khatiwada, K.P. Paudyal, B.R. Khadge, and H. N. Regmi.

Davis, P., Hoffman, R.C., Thatton, T., 1974. Temperature and duration of storage on ethanol content of citrus fruits. HorticSci., 9, Pp. 376-377.

ElShiekh, F.A., Abu-Goukh, A.A., 2008. Effect of Harvesting Method on Quality and Storability of Grapefruits. Univ. Khartoum J. Agric. Sci., 16 (1), Pp. 1–14.

Faasema, J., Abu, J.O., Alakali, J.S., 2011. Effect of packaging and storage condition on the quality of sweet orange (*Citrus cinesis*). Journal of Agriculture Technology, 7 (3), Pp. 797-804.

FAO. 2020. Handling of fresh fruits, vegetables and root crops, a training manual for Grenada, TCP/GRN/2901. http://www.fao.org/3/a-au186e.pdf (Accessed on 2020/11/03).

Jafarpour, M., Fatemi, S., 2012. Post-harvest treatments on shelf life of sweet orange "Valencia". Journal of Medicinal Plants Research, 6 (11), Pp. 2117-2124.

Joshi, P., Ojha, B.R., Kafle, A., 2020. Effect of Different Postharvest Treatments on Prolonging Shelf life of Citrus reticulata Blanco. Nepalese Horticulture, 14, Pp. 1-8. doi: https://doi.org/10.3126/nh.v14i1.30603

Kasso, M., Bekele, A., 2018. Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. Journal of the Saudi Society of Agricultural Sciences, 17 (1), Pp. 88-96.

Kitinoja, L., Kader, A., 2002. Small Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th edition). Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center. https://www.researchgate.net/publication/268296178_Small-Scale Postharvest Handling Practices A Manual for Horticultural Crops 4th Edition.

Kumargoud, V., Gowda, S.J., Karthik, S.K., and Mohithkumar, G.V., 2017. Performance evaluation of mango harvesting techniques. Agric. Update, 12 (TECHSEAR-4), Pp. 1135-1137. DOI: 10.15740/HAS/AU/12.TECHSEAR (4)2017/1135-1137.

Li, P., Lee, S., Hsu, H.Y., 2011. Review in fruit harvesting method for potential use of automatic fruit harvesting systems. Elsevier, Procedia Engineering, 23, Pp. 351-366. www.sciencedirect.com.

Liu, F.W., 2010. Development and application of citrus storage technologies with concurrent consideration of fruit quality preservation, energy use, and costs, 2010. AARDO workshop on technology on reducing post harvest losses and maintaining quality of fruits and vegetables, 26-47.http://210.69.150.18:8080/ir/bitstream/345210000/2816/1/publication_no147_07.pdf (Accessed on 2020/12/10).

Mahajan, B.V.C., Singh, R., Kumar, M., 2016. Quality assurance and shelf-life extension of kinnow mandarin fruit under supermarket conditions. International Journal of Fruit Science, 16 (1), Pp. 94–102. http://dx.doi.org/10.1080/15538362.2015.1061959

Mavis, O.A., Firibu, K.S., Samuel, S.D., 2014. Effect of Storage Time and Storage Conditions on Physicochemical Quality of Sweet Orange (Citrus sinensis L). Journal of Agriculture and Food Technology, 4 (5), Pp. 36-41.

MoALD. 2020. Statistical Information of Nepalese Agriculture (2018/19). Government of Nepal, Ministry of Agricultural and Livestock Development, Planning & Development Cooperation Coordination Division, Statistics and Analysis Section, Singha Durbar, Kathmandu, Nepal .

Panth, B.P., Dhakal, S.C., 2019. Determinants of mandarin productivity and causes of citrus decline in Parbat district, Nepal. Acta Scientific Agriculture, 3 (10), Pp. 14-19.

Purbiati, T., Supriyanto, A., 2013. Effect of harvesting methods and storage temperature on shelf life of mandarin fruit cultivar 'SoE' from East Nusa Tenggara, Indonesia. Acta Horticulture, International Society for Horticultural Science (ISHS), 989, Pp. 149-152. https://doi.org/10.17660/ActaHortic.2013.989.18

Rokaya, P.R, Baral, D.R, Gautam, D.M, Shrestha, A.K., Paudyal, K.P., 2016. Effect of Postharvest Treatments on Quality and Shelf Life of Mandarin (Citrus reticulata Blanco). American Journal of Plant Sciences, **7**, Pp. 1098-1105. doi: 10.4236/ajps.2016.77105.

Rokaya, P.R., Baral, D.R., Gautam, D.M., Shrestha, A.K., Paudyal, K.P., 2020. Effect of Harvesting Methods on Storage Behaviour of Mandarin (Citrus Reticulata Blanco) Under Cellar Condition. International Journal of Science and Qualitative Analysis, 6 (1), Pp. 8-12. doi: 10.11648/j.ijsqa.20200601.12

Rickman, J., Moreira, J., Gummert, M., Wopereis, M., 2013. Mechanizing Africa's rice sector. In : Wopereis, M.C.S., Johnson, D. E., Ahmadi,N., Tollens, E., Jalloh, A.(ed.), Realizing Africa's rice promise. Wallingford : CAB International, Wallingford,UK, Pp. 332-342.

Sabale, P.R., Nalawade, R.D., Bhosale, T.B., Menu, S.S., 2017. Development of Manual Orange (Citrus sinensis) Fruit Harvesting System. Int.J.Curr.Microbiol.App.Sci., 6 (11), Pp. 3427- 3433. doi:https://doi.org/10.20546/ijcmas.2017.611.403

Singh, B.P., Parla, S.K., Tonden, D.K., 1993. Effect of methods of harvesting on storage behaviour of mango. Indian Journal of Horticulture, 50 (1), Pp. 5-9.

Sonkar, P.K., Ladaniya, M.S., Singh, S., 1999. Effect of harvesting methods and post-harvest treatments on storage behaviour of Nagpur mandarin (Citrus reticulata) fruit. The Indian Journal of Agricultural Science, 69 (6), Pp. 1-6.

Ullah, F., Sajid, M., Gul, S.L., Zainub, B., Khan, M., 2018. Influence of hot water treatments on the storage life of sweet orange cv. sherkhana-I. Sarhad Journal of Agriculture, 34 (1), Pp. 220-224.

Waskar, D.P., Masalkar, S.D., Gaikwad, R.S., Damame, S.V., 1997. Effect of method of harvesting on post harvest loss reduction and extension of shelf life of mango. Acta Horticulturae, 455, Pp. 662-668. https://doi.org/10.17660/ActaHortic.1997.455.8.