The American Journal of Life Science and Innovation (AJLSI) is an international, open access, and blind peer-reviewed Journal that publishes research articles emphasizing life sciences and innovations. The Journal comprises techniques suitable for promoting the dissemination of research findings that are expected to benefit the basic needs of health, agriculture, biotechnology, pharmaceutical, and food industries. AJLSI also publishes life science articles on evidence-based practices, thus improving the quality of life. AJLSI accepts manuscripts throughout the year; all submitted manuscripts are rigorously reviewed, and publish articles online first.

**Frequency:** 3 issues per year

**Area of publication:** Life science and technologies, innovations in life sciences and development of living orgasms, and related fields.

**Editorial Team**

**Professor Dr. Nirmal Chandra Roy**  
Sylhet Agricultural University, Bangladesh

**Dr. Sejuti Mondal**  
Texas State University, USA

**Dr. Sandra Milena Camargo Silva**  
Materials Engineering, Pedagogical and Technological University of Colombia, Colombia

**Dr. Myint Thuzar**  
Professor, Yezin Agricultural University (YAU)  
Myanmar

**Dr. Md. Morshedur Rahman**  
Professor, Department of Dairy and Poultry Science  
Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

**Dr. Omar Faruk Miazi**  
Professor, Department of Genetics and Animal Breeding  
Chattogram Veterinary and Animal Sciences University (CVASU)  
Chattogram, Bangladesh

**Dr. Yulianna Puspitasari**  
Faculty of Veterinary Medicine, Universitas Airlangga  
Surabaya, Indonesia

**Dr. Md Robiul Karim**  
Associate professor, Department of Medicine  
Bangabandhu Sheikh Mujibur Rahman Agricultural University  
Gazipur, Bangladesh

**Dr. Mst. Rubia Banu**  
Assistant Professor, Department of Fisheries Management  
Bangabandhu Sheikh Mujibur Rahman Agricultural University  
Gazipur, Bangladesh

**Dr. Tilak Chandra Nath**  
Associate professor, Department of Parasitology  
Sylhet Agricultural University, Bangladesh

**Professor Dr. Mrityunjoy Kunda**  
Dean, Faculty of Fisheries  
Sylhet Agricultural University, Bangladesh

**Contact:**  
American Journal of Life Science and Innovation (AJLSI)  
E-Palli LLC  
Address: 2055 Limestone Rd Ste 200C, Zip Code: 19808, Wilmington, Delaware, USA  
Email: ajlsi@e-palli.com  
Phone: +1 3024070506  
URL: https://journals.e-palli.com/home/index.php/ajlsi
Evaluation of Low Chilling Strawberry (Fragaria ananassa) Varieties with Respect to Yield and Quality in Eastern Nepal

S. Dhakal\textsuperscript{1}, D. Shashan\textsuperscript{2}, B. Shrestha\textsuperscript{3}

ABSTRACT

The experiment entitled “Evaluation of low chilling strawberry (Fragaria ananassa) varieties with respect yield and quality in eastern Nepal” was conducted in Dharan and Biratnagar of Nepal with five varieties ‘EMCO 33’, ‘EMCO 32’, ‘Florida Fortuna’, ‘Florida Beauty’ and ‘Sweet Sensation’. The experiment was laid out in Factorial RCBD where variety and location was considered as factors. From the experiment highest number of fruits per plot (13.22) and maximum fruit set (95.72%) was recorded with variety ‘EMCO 33’. However, maximum number of fruits per plot (444.25) with only 14.04 % of unmarketable fruit and highest yield of 9068.75 grams per plot with 7976.00 grams of marketable yield per plot was obtained with variety ‘EMCO 32’ in Dharan. Comparing the length and diameter of fruit variety ‘EMCO 32’ (49.00 cm×43.42 cm) and variety ‘EMCO 33’ (49.04 cm×38.41 cm) seems more appealing in form, pH, vitamin C and TA content was found higher in variety ‘EMCO 33’ (3.48, 71.89 mg/g and 0.90 % respectively) and higher TSS content (6.57 0 Brix) was obtained with variety ‘EMCO 32’ with no interaction effect for quality traits. Thus among treatment combinations variety ‘EMCO 32’ followed by ‘EMCO 33’ in Dharan conditions is more preferable to other treatments and also both the varieties perform well compared to other varieties in Biratnagar conditions also. However still more studies are required to assess the varietal performance and it would be premature to recommend suitable variety for given locations.

INTRODUCTION

The modern cultivated strawberry (Fragaria ananassa Duch.) is a hybrid of two largely dioecious, octoploid species, Fragaria cheloneis Duch and Fragaria virginiana Duch belonging to family Rosaceae. Basically, it is herbaceous perennial and short day plant. It grows predominantly in the temperate climate but worldwide it is the most widely distributed fruit crop due to its genetic diversity, highly heterozygous nature and broad range of environmental adaptation (Anderson and Guttridge, 1982; Dale et al., 2000).

Strawberry is cultivated in limited regions of Nepal in Nuwakot district and its periphery and choice of varieties is limited to Nyoho, Ohno, Eyeberry and Akhime. Productivity of strawberry in Nepal is only 9 mt/ha compared to world productivity 23.58 mt/ha (DADO, 2017; FAO, 2019). Because of limited research, strawberry cultivation is still in womb stage in Nepal. Only limited varieties are available. Previously, Nyoho variety was widely cultivated recently, Ankhime and Eyeberry varieties are also introduced. Cultivation of strawberry on other hand is concentrated in hilly areas of Nepal potential areas has not been identified no studies on strawberry in terai is conducted Strawberry once thought to be temperate fruit can be grown in tropical areas too. Since strawberry is high value fruit, more potential areas need to be identified and tropical low chilling requiring varieties need to be explored. So, 5 low chilling strawberry varieties ‘Florida Beauty’, ‘Sweet Sensation’, ‘Fortuna’, ‘EMCO 32’ and ‘EMCO 33’ were studied in two domains Biratnagar and Dharan in eastern Nepal to compare their performance under different growing condition with following objectives:

• To study the comparative yield performance of low chilling required five strawberry varieties in two locations
• To assess the quality of fruit of different strawberry varieties under different growing location.

LITERATURE REVIEW

World Production of strawberry is in increasing trend, it was 4.4 million tonnes in 2000 AD to 9.2 million tonnes in year 2017 (FAO, 2019) which is almost twice. China leads the world Production with 3.7 million tonnes in year 2017 A.D which is almost one third of world production while USA has highest productivity of 67 tonnes/ha. Here in Nepal strawberry production is concentrated in Nuwakot District covering area of 55 ha and the production is around 495 mt where 254 families are involved in strawberry cultivation (DADO, 2017). Nepal imports 10,826 Kg of strawberry annually which is worth NRs 2.1 million (TEPC, 2019). The Japanese first saw the potential for strawberry farming in Kakani 25 km to the north of Kathmandu ,25 years ago when agronomist Matsuura Hiroshi brought six sample plants which flourished and spread among farmers who till then had been growing radish for the Kathmandu market, in 1991. The variety of strawberries cultivated in Nepal Akhime, Nyoho, require an altitude of 1500 - 2500m with a temperature range of 4-25 degree Celsius and 3000-4000 ml of rainfall, making Kakani the ideal location (Nepali Times, 2017). Currently more than 700 households are involved in commercial farming.
each producing approximately 1000kg of strawberries per season (MEDEP, 2010). Nuwakot district has been gaining prominence in strawberry cultivation as a summer fruit. Kakani and Okharpauwa VDCs are regarded as the pocket area for strawberry cultivation. Once suitable temperature and day length conditions are met, strawberry flower buds are initiated. Initially, the apical meristem broadens, then the sepal, petal, stamen and carpel primordia develop in sequence and start to enlarge (Darrow, 1966; Darnell, 2003).

The primary flower emerges first, followed by the secondary, tertiary and quaternary flowers (Hancock, 1999). Typically the inflorescence includes one primary flower and two or three, or sometimes four, secondary flowers terminally on individual branches of the main stem (Darnell, 2003). At least 30% of the carpels need to be fertilized for fruit to develop good shape (Day, 1993), although Guttridge (1979) reported 70-80% were needed.

Strawberry fruit development can be divided into several stages: small green, large green, white, pink and red. The weight and size of the fruit is largest at the red stage (Darrow, 1966; Abeles and Takeda, 1990).

When fruits take about 30 days to develop from bloom to ripening, cell division occurs first and ends 10-15 days after anthesis (Cheng & Breen, 1992). Then the cells enlarge and expand towards the inside of the fruit. However, although the cells divide and expand, the main factor which causes the variation in fruit size is the number of cells at anthesis (Cheng & Breen, 1992). Cell division contributes between 15-20% of the total growth. The remaining growth comes from cell enlargement by cells expanding towards inside of the fruit (Hancock, 1999).

Many day-neutral strawberry cultivars require a dormancy period of between 675 and 1000 hours in a conditions of -1 to 10°C C (Stewart & Folta, 2010). Studies show day/night temperatures of 18/14°C as the ideal for fruit production (Hancock, 1999).

Heat stress is a challenge in strawberry production that has been reported all over the world. In general, strawberry plants under heat stress grow more slowly, and produce fewer and smaller fruit (Renquist et al., 1982; Hellman and Travis, 1988).

Temperature and photoperiod are the two major factors which influence the transition from vegetative to floral growth. Flower bud initiation is inhibited when temperatures are above 12 to 28°C depending on day length and flowering type (Chabot, 1978; Okimura and Igarashi, 1997; Dale et al., 2009).

One recent study showed that the developmental stages of flower buds in ‘Akihime’ strawberry were significantly larger at 22°C than those of the untreated plants (Kim et al., 2009).

Fruit number per plant decreases as temperature increases. In ‘Nyoho’ and ‘Toyonoka’ the numbers of fruit were greatly reduced at 30/25°C when compared to 23/18°C (Ledesma et al., 2008). When the day-time and night-time effects were investigated, fruit size was smaller under day-time temperatures over 15-17°C and largest at 12°C night temperature. (Went, 1957; Sato & Hiraoka, 1971)

Sweet Sensation® is a new strawberry cultivar released from the University of Florida in 2013, commonly known as ‘Florida 127’ in US and Canada originally evaluated as breeding selection FL 09-127. ‘Florida127’ originated from a 2009 cross between WinterStar™ ‘FL 05-107’ (female parent) and unreleased breeding selection FL 02-58 (male parent) (Whitaker et al., 2017).

‘Florida Fortuna’ a strawberry variety released by US is known as ‘Florida Radiance’ in US and Canada released from UF/IFAS in 2008 (Chandler et al. 2009) originated from a 2001 cross between ‘Winter Dawn’ (female parent), a 2005 release from the UF/IFAS breeding program, and FL 99-35 (male parent) (Whitaker et al., 2019).

‘Florida Beauty’ (PPAF) is a new strawberry cultivar released by the University of Florida and commercialized in 2017. This cultivar was originally evaluated as breeding selection FL 12.121-5. ‘Florida Beauty’ originated from a 2012 cross between Queensland Australia selection 2010-119 (female parent) and ‘Florida Radiance’ (male parent) (Whitaker et al., 2017a).

‘Florida127’ is a short-day plant adapted to annual, winter plasticulture growing systems. The plant is moderately compact, robust, and upright with long pedicels, making the fruit easy to harvest producing conic to broad-conic fruit that are uniform in shape throughout the season, resulting in few non-marketable fruit (Whitaker et al., 2017).

“Florida Fortuna” produces conic to long-conic fruit that are very large, uniform, glossy, and evenly coloured. “Florida Fortuna” has a weak plant habit and can benefit from extra chilling hours in the nursery. While it requires little chilling to initiate flower buds compared to typical short-day cultivars, increased chilling may be important to increase production (Whitaker et al., 2019).

Whitaker et al. (2017) stated that Florida Fortuna’ fruit size is larger than the other cultivars late in the season. The fruit has a moderate acid content with a balanced flavor and is generally the juiciest of the UF/IFAS cultivars. Both early season and late-season yields of ‘Florida Fortuna’ in Florida have been higher than any other UF/IFAS cultivar in most seasons. In an experiment conducted in Queensland to compare varieties ‘Florida Beauty’ cultivar has excellent fruit quality, with flavour often similar to ‘Sweet Sensation’ and sufficient quality to be marketed at retail under the ‘Sweet Sensation®’ brand. Early and total season yields of ‘Florida Beauty’ have been very similar to ‘Florida Fortuna’, which can produce elongated fruit in the early season. When planted at later dates around Oct 10, ‘Florida Beauty’ has had lower yields than ‘Florida Fortuna’ due to its more compact plant size (Whitaker et al., 2017a).

Whitaker et al. (2017) stated that Fruit size of ‘Sweet Sensation’ is very large, exceeding that of ‘Florida
Fortuna’ on average over the course of the season. Fruit firmness is slightly greater than that of ‘Florida Fortuna’, with excellent shelf life. Average fruit weight of ‘Sweet Sensation’ Florida Fortuna and ‘Florida Beauty’ is 35-45 gm, 30-40 gm and 27-37 gm respectively as recorded in U.S. Plant Patent (United States Patent No. USOOPP20363P2, 2009; United States Patent No. US 20140359905P1, 2014; United States Patent No. USOOPP30385P3, 2019)

In an experiment conducted to compare 3 varieties of strawberry average marketable yield of 803.6 gm per plant was recorded with ‘Sweet Sensation’ being at par with ‘Florida Fortuna’ i.e. 749.7 gm per plant and lowest yield was recorded with ‘Florida Beauty’ i.e. 601.3 gm per plant with average weight per fruit being 30.8 gm, 25.0 gm and 22.3 gm respectively (Whitaker et al., 2015).

In an experiment in university of Florida it was recorded the pH of Florida Fortuna was 3.6 and that of ‘Sweet Sensation’ was 3.7. But ‘Sweet Sensation’ was superior for sweetness compared to ‘Florida Fortuna’ with total soluble solid content 7.5 % and 5.3 % respectively (Whitaker et al., 2015). It is estimated that the picking interval should be one day longer for ‘Sweet Sensation’ than for ‘Florida Fortuna’ at most points during the season. The ripe fruit of ‘Florida127’ have excellent flavour and aroma. Soluble solids contents of ‘Sweet Sensation’ fruit were significantly higher than those of ‘Florida Fortuna’ on six of seven harvest dates tested. Titratable acidity was not significantly different from ‘Florida Fortuna. Significant difference in TSS/TA ratio was observed in variety ‘Sweet Sensation’ and ‘Florida Fortuna’ with ratio being 10.8 and 6.4 respectively (Whitaker et al., 2015).

METHODS
Treatment details
Different low chilling strawberry varieties and two locations were considered as factors in combination. Therefore, there were two different factors in this research which are shown below.

Factor 1: Location
The experiment was conducted in two locations to evaluate the performance of strawberry in different ecological zones. Two ecological regions Biratnagar and Dharan were selected to conduct the varietal research trial on strawberry.

Biratnagar
The city is located in the Morang District of province 1 has a total area of 77.5 km². The geographical location is 26°28'60"N 87°16'60"E. In Biratnagar, the average annual temperature is 24.3 °C. The rainfall here averages 1898 mm.

Dharan
The city is located in the Sunsari District of province 1 has a total area of 192.61 km². The geographical location is 26°49'0"N 87°17'0"E. The city experiences sub-tropical climate situated at altitude of 349 masl. In Dharan, the average annual temperature is 23.2 °C. The rainfall here averages 1799 mm.

Figure 1. Average weather data of Biratnagar and Dharan from November 2018 to May 2019

Factor 2: Variety (V)
Five low chilling strawberry varieties were used to evaluate their relative performance. The varieties used were

V1 = Florida Beauty
V2 = Sweet Sensation
V3 = Fortuna
V4 = EMCO 32
V5 = EMCO 33

Experimental design
The trial was laid out in Randomised complete block design (RCBD) design with 4 replications and 5 varietal treatment in each location. The area of experimental field was 297 m² with length and breadth of main field 45 m × 6.6 m respectively. Distance between replications was maintained at 1 m and treatments were laid 50 cm apart. With spacing of 38 cm × 28 cm (RR × PP), 52 plants per plot were maintained.

Planting techniques
Strawberries were planted in a raised bed with double row system. Following schematic diagram was followed for raised bed system.

Planting material and Planting
Bare root strawberry transplants were used as planting
material. The bare root strawberry transplants were transplanted in raised plastic-mulched beds at spacing of 38 cm × 28 cm. Planting was done on Nov 13, 2018. One week of overhead sprinkler irrigation was provided for one week to ensure plant establishment.

**Parameters studied**

Various yield and quality parameters of randomly selected and properly tagged sample plants were evaluated.

**Fruit yield parameters**

Fruit set percentage (%), Number of fruit per plant, Number of fruits per plot, Number of marketable plot, Marketable yield per plot (grams) and Fruit yield per plot (grams) were recorded.

**Fruit quality parameters**

Total Soluble Solids (TSS), pH of strawberry, Titrable acidity (%), Ascorbic acid (Vitamin C) content (mg/100g)

**Data analysis**

All data recorded were processed using Microsoft Excel. Statistical analysis and relation among treatments was established for the selected parameters with reference to Gomez and Gomez, 1984. Different statistical tools as R and EXCEL were used for the analysis of variance, DMRT test and other data analysis as required.

![Figure 2. Double row system of strawberry planting](image)

**RESULTS AND DISCUSSION**

**Phenological characters**

Table 1. Phenological characters of strawberry (Fragaria ananassa) as influenced by varieties and different locations of Nepal in 2018/2019.

**Effect of location on phenological characters**

Phenological characters of different varieties of strawberry as influenced by location is presented in Table 1. Days to First flowering, Number of flowers per plant, fruit set % and number of fruits per plant are found significantly different statistically at different locations. Earlier flowering (14.52 DAT), higher number of flowers per plant (13.79) was observed in Biratnagar being statistically different to days to first flowering (16.11 DAT) and number of flowers per plant in Dharan (10.76). However, fruit set percentage is found significantly higher in Dharan (89.48 %) compared to Biratnagar (70.82 %). No significant effect was seen regarding number of fruits per plant which might be due to low fruit set % in Biratnagar though higher number of flowers were

| Treatments | Days to first flowering | Number of flowers per plant | Number of fruits per plant | Fruit set % |
|------------|-------------------------|-----------------------------|----------------------------|-------------|
| Location (Factor A) |                         |                             |                            |             |
| Dharan     | 16.11<sup>a</sup>       | 10.76<sup>b</sup>           | 10.06                      | 89.48<sup>a</sup> |
| Biratnagar | 14.52<sup>b</sup>       | 13.79<sup>a</sup>           | 9.64                       | 70.82<sup>b</sup> |
| Grand Mean | 15.31                   | 12.28                       | 9.85                       | 80.15        |
| SEM        | 1.53<sup>b</sup>        | 2.46**<sup>b</sup>          | 1.12**<sup>b</sup>         | 8.60***<sup>b</sup> |
| LSD        | 1.28                    | 2.24                        | 1.02                       | 7.78         |
| CV         | 29.87                   | 28.49                       | 16.12                      | 15.17        |
| Variety (Factor B) |                         |                             |                            |             |
| EMCO33     | 10.83<sup>c</sup>       | 16.90<sup>c</sup>           | 11.60<sup>bc</sup>         | 88.37<sup>c</sup> |
| Sensation  | 22.62<sup>c</sup>       | 8.43<sup>d</sup>            | 6.10<sup>d</sup>           | 64.46<sup>c</sup> |
| Florida Beauty | 13.61<sup>c</sup> | 12.09<sup>bc</sup>          | 10.39<sup>b</sup>          | 73.63<sup>bc</sup> |
| EMCO32     | 7.91<sup>d</sup>        | 14.10<sup>b</sup>           | 12.60<sup>a</sup>          | 88.92<sup>a</sup> |
| Fortuna    | 21.6<sup>c</sup>        | 9.85<sup>d</sup>            | 8.57<sup>c</sup>           | 85.39<sup>bc</sup> |
| Grand Mean | 15.31                   | 12.28                       | 9.85                       | 80.15        |
| SEM        | 1.78**<sup>c</sup>      | 1.66**<sup>c</sup>          | 1.12**<sup>c</sup>         | 8.80***<sup>c</sup> |
| LSD        | 2.56                    | 2.38                        | 1.61                       | 12.62        |
| CV         | 16.47                   | 19.15                       | 16.12                      | 15.51        |

Means with same letter within column do not differ significantly at p= 0.05 by DMRT. NS- Non –significant, SEM- Standard error of mean, LSD- Least significant difference, CV- Coefficient of variance, DAT- Days After Transplanting.
obtained in Biratnagar.

**Effect of varieties on phenological characters**

Effect of variety on phenological characters of strawberry plants is presented in Table 1. Days to First flowering, Number of flowers per plant, fruit set % and number of fruits per plant are found significantly different statistically among different varieties. Earlier flowering (7.91 DAT), higher fruit set (88.92 %) and higher number of fruits per plant (12.55) was obtained in variety ‘EMCO 32’ whereas late flowering (22.62 DAT), least fruit set percentage (64.46 %) and least number of fruits per plant (6.10) was obtained in variety ‘Sweet Sensation’.

However highest number of flowers per plant (16.90) were recorded in variety ‘EMCO 33’ whereas least number of flowers per plant (8.43) was obtained in variety ‘Sweet Sensation’ being statistically similar to variety ‘Florida Fortuna’ (9.85).

**Table 2. Interaction effect on phenological characters of strawberry (Fragaria ananassa) varieties at different locations of Nepal in 2018/2019.**

| Treatments                        | Days to first flowering | Number of flowers per plant | Number of fruits per plant | Fruit set % |
|-----------------------------------|-------------------------|------------------------------|----------------------------|-------------|
| Location × variety interaction    |                         |                              |                            |             |
| Dharan.EMCO33                     | 12.12                   | 14.31                        | 13.22                      | 95.72       |
| Dharan.Sensation                  | 26.65                   | 7.25                         | 6.9                        | 73.75       |
| Dharan.Beauty                     | 11.97                   | 10.36                        | 9.43                       | 93.89       |
| Dharan.EMCO32                     | 6.60                    | 15.57                        | 12.01                      | 94.68       |
| Dharan.Fortuna                    | 23.20                   | 9.24                         | 8.67                       | 89.37       |
| Biratnagar.EMCO33                 | 9.55                    | 19.5                         | 9.99                       | 51.54       |
| Biratnagar.Sensation              | 18.6                    | 9.62                         | 5.29                       | 55.17       |
| Biratnagar.Beauty                 | 15.25                   | 13.82                        | 11.35                      | 82.05       |
| Biratnagar.EMCO32                 | 9.22                    | 16.27                        | 13.10                      | 83.95       |
| Biratnagar.Fortuna                | 20.00                   | 10.46                        | 8.48                       | 81.40       |
| Grand Mean                        | 15.31                   | 12.28                        | 9.85                       | 80.15       |
| SEM                               | 0.64**                  | 1.18**                       | 0.94**                     | 1.73***     |
| LSD                               | 1.30                    | 2.42                         | 1.90                       | 3.53        |
| CV                                | 5.88                    | 13.67                        | 13.42                      | 3.05        |

Means with same letter within column do not differ significantly at p= 0.05 by DMRT. NS- Non –significant, SEM- Standard error of mean, LSD- Least significant difference, CV- Coefficient of variance, DAT- Days After Transplanting

**Interaction effect of location and variety for phenological characters**

Interaction effect of location and variety on phenological characters of strawberry plants is presented in Table 2. Days to First flowering, Number of flowers per plant, fruit set % and number of fruits per plant are found significantly different statistically among different varieties at different locations. Earlier flowering (6.60 DAT) was obtained in Dharan with variety ‘EMCO 32’ followed by variety ‘EMCO 32’ in Biratnagar (9.22 DAT) whereas late flowering (26.65 DAT) was obtained in Dharan with variety ‘Sweet Sensation’.

The result reveals that although in overall performance there is late flowering in Dharan but still from interaction effect it is evident that earlier flowering variety ‘EMCO 32’ performs better in Dharan. Significantly higher number of flowers per plant (19.50) was recorded in Biratnagar with variety ‘EMCO 33’ followed by variety ‘EMCO 32’ in Biratnagar (16.27) whereas least number of flowers (7.25) were obtained in Dharan with variety ‘Sweet Sensation’ being statistically similar to variety ‘Florida Fortuna’ in Dharan (9.24).

Significantly higher fruit set (95.72 %) was recorded in Dharan with variety ‘EMCO 33’ being statistically at par with variety ‘EMCO 32’ in Dharan (94.68 %) and also with variety ‘Florida Beauty’ in Dharan (93.89 %) whereas least fruit set (51.54 %) percentage was recorded in variety ‘EMCO 33’ in Biratnagar followed by variety ‘Sweet Sensation’ in Biratnagar (55.17 %). Significantly higher number of fruits per plant (13.22) was recorded in Dharan with variety ‘EMCO 33’ being statistically at par with variety ‘EMCO 32’ in Biratnagar (13.10) whereas least number of fruits per plant (5.29 ) was recorded in Biratnagar with variety ‘Sweet Sensation’ followed by variety ‘Sweet Sensation’ in Dharan (6.9).

From results presented in table 1 and table 2 we can conclude that larger number of flowers are obtained in Biratnagar with variety ‘EMCO 33’ but variety ‘EMCO 32’ performed better than variety ‘EMCO 33’ in Dharan. Interaction effect shows that for phenological characters variety ‘EMCO 33’ is more suitable for Dharan and...
Variety ‘EMCO 32’ is more suitable for Biratnagar. Earlier flowering in Biratnagar conditions contradicts with findings of Kurian (2015), that earlier flowering was observed in high altitude. The favourable temperature and day condition, prevailing in Biratnagar may have influence on early flowering in Biratnagar. Earlier flowering in variety ‘EMCO 32’ might be attributed to its day neutral behaviour. Variability in flowering period in different varieties might also be due to differences in their chilling requirement as suggested by Joolka and Badiyala (1983). Number of leaves per plant, leaf area and number of crowns per plant are positively correlated with number of flowers per plant (Girijalba et al., 2015) which might be reason for higher number of flowers in Dharan and in variety ‘EMCO 32’ and ‘EMCO 33’.

Variation in number of fruits per plant might be due to differential fruitset % among varieties in different location. Lower fruit set % but higher number of flowers in Biratnagar conditions resulted in insignificant difference in number of fruits per plant among locations. The variation in fruit set % may be due to genetic makeup of the cultivars and adaptation to climatic condition (Jami et al., 2015).

### Yield per plot

| Treatments          | Marketable Yield per plot (gm) | Total Yield per plot (gm) |
|---------------------|--------------------------------|---------------------------|
| Location (Factor A) |                                 |                           |
| Dharan              | 4101.20                         | 4720.75<sup>a</sup>       |
| Biratnagar          | 2794.33                         | 3244.81<sup>b</sup>       |
| Grand Mean          | 3447.76                         | 3982.78                   |
| SEM                 | 935.47<sup>ns</sup>            | 1066.73<sup>***</sup>     |
| LSD                 | 1693.84                         | 1931.50                   |
| CV                  | 26.74                           | 25.75                     |
| Variety (Factor B)  |                                 |                           |
| EMCO33              | 6034.68<sup>a</sup>            | 6932.97<sup>a</sup>       |
| Sensation           | 1558.25<sup>b</sup>            | 1848.25<sup>b</sup>       |
| Florida Beauty      | 1541.25<sup>b</sup>            | 1831.12<sup>b</sup>       |
| EMCO32              | 6844.64<sup>a</sup>            | 7828.32                   |
| Fortuna             | 1260.00<sup>b</sup>            | 1473.25<sup>b</sup>       |
| Grand Mean          | 3447.76                         | 3982.78                   |
| SEM                 | 384.23<sup>***</sup>           | 446.85<sup>***</sup>      |
| LSD                 | 1103.12                         | 1282.91                   |
| CV                  | 31.52                           | 31.73                     |

**Effect of location on Yield per plot**

Yield per plot of different varieties of strawberry as influenced by location is presented in Table 3. Marketable yield per plot and in relation to location was found statistically insignificant whereas weight of total yield per plot was found statistically significant. Significantly higher total yield was obtained in Dharan (4720.75 gm) compared to Biratnagar (3244.81 gm).

**Effect of Variety on yield per plot**

Effect of variety number of fruits per plot of strawberry plants is presented in Table 3. Marketable yield per plot and yield per plot in relation to location are found significantly different statistically among different varieties. Highest marketable yield per plot (6844.64 gm) and highest total yield per plot (7828.32 gm) was recorded in variety ‘EMCO 32’ being statistically at par with variety ‘EMCO 33’ for marketable yield (6034.68 gm) and total yield (6932.97 gm) per plot whereas least marketable yield per plot (1260.00 gm) and least total yield per plot (1473.25 gm) was obtained in variety ‘Florida Fortuna’ being statistically at par with variety ‘Sweet Sensation’ (1558.25 gm).

Differences in survivability and yield per plant of different varieties may be reason behind difference in number of fruits per plot of strawberry.

**Interaction effect of location and variety on yield per plot**

Interaction effect of location and variety on number of fruits per plot of strawberry plants is presented in Table 4. Marketable yield per plot and total yield per plot are found significantly different statistically among different varieties at different locations. Higher marketable yield per plot (7976.00 gm) was recorded in Dharan with variety ‘EMCO 32’ being statistically at par with variety ‘EMCO 33’ (7116.75 gm) in Dharan. Similarly in Biratnagar conditions also variety ‘EMCO 32’ had highest marketable yield per plot (5713.28 gm). Whereas least marketable yield per plot (682.00 gm) was obtained in Biratnagar with variety ‘Florida Fortuna’. Lowest unmarketable yield per plot (192.00 gm) was recorded in Biratnagar with variety ‘Florida Fortuna’ being statistically at par with variety ‘Florida Fortuna’.
(222.00 gm) in Dharan being statistically at par with variety 'Sweet sensation' (264.00 gm) in Dharan. Whereas highest unmarketable yield per plot (1243.25 gm) was obtained in Dharan with variety 'EMCO 33'. Higher total yield per plot (9068.75 gm) was recorded in Dharan with variety 'EMCO 32' being statistically at par with variety 'EMCO 33' (8360.00 gm) in Dharan. Similarly in Biratnagar conditions also variety 'EMCO 32' had highest total yield per plot (6587.90 gm). Whereas lowest total yield per plot (874.00 gm) was obtained in Biratnagar with variety 'Florida Fortuna'. The result presented in table 16 and table 17 reveals that variety 'EMCO 32' followed by variety 'EMCO 33' performed best in both locations and Dharan conditions was more favourable for yield per plot. Also higher unmarketable yield per plot were related with higher total yield of fruits. The differences for total yield per plot may be attributed to difference in plant survivability and number of fruits per plot.

**Effect of location on fruit quality parameter**

| Treatments | Marketable Yield per plot (gm) | Total Yield per plot (gm) |
|------------|--------------------------------|--------------------------|
| Dharan.EMCO33 | 7116.75a                      | 8360.00*                 |
| Dharan.Sensation | 1786.50c                      | 2050.50c                 |
| Dharan.Beauty | 1788.75c                       | 2052c                    |
| Dharan.EMCO32  | 7976.00a                       | 9068.75a                 |
| Dharan.Fortuna | 1838.00c                       | 2072.50c                 |
| Biratnagar.EMCO33 | 4952.62b                      | 5505.94b                 |
| Biratnagar.Sensation | 1330.00c                      | 1646.00c                 |
| Biratnagar.Beauty  | 1293.75c                       | 1610.25c                 |
| Biratnagar.EMCO32  | 5713.28b                      | 6587.90b                 |
| Biratnagar.Fortuna | 682.00c                       | 874.00c                  |
| Grand Mean | 3447.76                         | 3982.78                  |
| SEM | 275.01*                        | 314.36*                  |
| LSD | 1123.28                        | 1284.04                  |
| CV | 22.56                           | 22.32                    |
| CV | 31.52                           | 31.73                    |

Means with same letter within column do not differ significantly at p= 0.05 by DMRT. NS- Non -significant, SEM- Standard error of mean, LSD- Least significant difference, CV- Coefficient of variance, DAT- Days After Transplanting

Significant difference between locations was recorded for quality parameters TA, pH and Vit-C content of fruits and no significant difference between locations for TSS was recorded , fruit quality parameter of different varieties of strawberry as influenced by location are presented in Table 5.

Significantly higher pH value (3.28) and TA content (0.85 % citric acid ) of fruit was observed in Biratnagar compared to pH (3.17) and TA content (0.80 % citric acid) in Dharan

Higher vitamin C content (68.22 mg/100gm) was recorded in Dharan being significantly different to Biratnagar (64.47 mg/100gm).

**Effect of varieties on fruit quality parameters**

Significant difference among varieties were recorded for quality parameters TSS content, pH, Vit- C content and TA of fruits as presented in Table 5.

Highest pH value (3.48), highest TA content (0.90% citric acid), higher vitamin C content (71.89 mg/100 gm) was recorded in variety 'EMCO 33' whereas least pH value (3.07), least TA content (0.77 % citric acid) and least Vit-C content (59.75 mg/100gm) was recorded in variety 'Sweet Sensation',

Highest TSS content (6.57 0B) was recorded in variety 'EMCO 32' whereas least TSS content (5.6 0B) was recorded in variety 'EMCO 33'. Variety 'Sweet Sensation' (6.12 0B) was found statistically at par with Variety 'Florida Beauty' (6.150B) and 'Florida Fortuna' (6.12 0B).

**Interaction effect of location and variety on Fruit quality parameters**

No significant effect of interaction of location and variety were recorded for quality parameters TSS content, pH, Vitamin - C content and TA of fruits.

Above results reveal that variety 'EMCO 32' and 'EMCO 33' were superior to other varieties as sweetness of fruit is related with TSS and TA content of fruit and variety 'EMCO 33' had higher vitamin-C content. Thus variety 'EMCO 33' is more preferable. Whitaker et al. (2015) and Kelly et al. (2016) also obtained similar results with physiochemical characters of strawberry fruits. Higher TSS and ascorbic acid content of fruit may be attributed to higher vegetative growth as enough
Table 5: Fruit quality parameters of strawberry (Fragaria ananassa) varieties as influenced by different locations of Nepal in 2018/2019.

| Treatments          | pH  | TSS | TA  | Vit-C |
|---------------------|-----|-----|-----|-------|
| **Location (Factor A)** |     |     |     |       |
| Dharan              | 3.17\(^b\) | 6.04 | 0.80\(^b\) | 68.22\(^a\) |
| Biratnagar          | 3.28\(^a\) | 6.19 | 0.85\(^b\) | 64.47\(^b\) |
| Grand Mean          | 3.22 | 6.11 | 0.82 | 66.35 |
| SEM                 | 0.11\(^***\) | 0.24\(^a\) | 0.04\(^***\) | 4.69\(^**\) |
| LSD                 | 0.10 | 0.21 | 0.03 | 4.1 |
| CV                  | 4.94 | 5.51 | 6.89 | 9.99 |
| **Variety (Factor B)** |     |     |     |       |
| EMCO33              | 3.48\(^a\) | 5.6\(^c\) | 0.90\(^a\) | 71.89\(^a\) |
| Sensation           | 3.07\(^c\) | 6.12\(^b\) | 0.77\(^b\) | 59.75\(^b\) |
| Florida Beauty      | 3.24\(^b\) | 6.15\(^b\) | 0.83\(^a\) | 67.22\(^a\) |
| EMCO32              | 3.08\(^c\) | 6.57\(^a\) | 0.85\(^b\) | 60.99\(^b\) |
| Fortuna             | 3.25\(^b\) | 6.12\(^b\) | 0.78\(^a\) | 71.89\(^a\) |
| Grand Mean          | 3.22 | 6.11 | 0.82 | 66.35 |
| SEM                 | 0.06\(^***\) | 0.10\(^***\) | 0.03\(^***\) | 3.25\(^**\) |
| LSD                 | 0.08 | 0.14 | 0.04 | 4.66 |
| CV                  | 2.44 | 2.35 | 4.89 | 6.91 |

photosynthetic was available for sugar and acid accumulation (Singh et al., 2007). TSS content was observed by the treatment which may be due to favorable temperature and humidity especially in night during fruit growth and ripening period. The soluble solids content was more dependent on environmental condition during growth and development than genetic inheritance in strawberry (Shaw, 1990).

The possible explanation for lower acidity in Dharan may be due to difference between day and night temperature which are very narrow, whereas cooler nights and warmer days are helpful in synthesizing more acidity noticed by Wani et al. (2007).

The oxygen concentration which is more in the lower altitude of the earth caused oxidation of more ascorbic acid, consequently fruits showed decreased ascorbic acid content in comparison to the fruits obtained and analyzed at higher altitude. In this support Klimczac and Stropek (1988) reported that strawberries grown at higher altitude have higher ascorbic acid content.

**CONCLUSION**

The experiment brought some important information on effect of location and variety on Yield and fruit quality parameters of strawberry.

For flowering and yield characters, variety ‘EMCO 32’ followed by ‘EMCO 33’ were superior both in Dharan and Biratnagar. But considering the overall production performance Dharan conditions were favourable than Biratnagar for given varieties. Fruit quality parameters are not of major importance in Nepal but Considering fruit quality variety ‘EMCO 33’ was more preferable with higher TSS, TA, Vitamin C and pH content while variety ‘EMCO 32’ had poor quality parameters and better quality fruits were obtained in Biratnagar. Thus we can conclude that among the varieties under study, variety ‘EMCO 33’ and ‘EMCO 32’ can successfully be cultivated in both locations and taking fruit quality parameters into consideration variety ‘EMCO 33’ is more preferable. However still more studies are required to assess the varietal performance and it would be premature to recommend suitable variety for given locations.

**REFERENCES**

Ables, F. B., & Takeda, F. (1990). Cellulase activity and ethylene in ripening strawberry and apple fruits. *Sci. Hort.*, 42, 269-275.

Anderson, H. M., & Guttridge, C. G. (1982). Strawberry truss morphology and the fate of high-order flower buds. *Crop Res.*, 22, 105-122.

Chabot, B. F. (1978). Environmental influences on photosynthesis and growth in Fragaria vesca. *New Phytol.*, 87-98.

Chamorro, M., Aguado, A., & De Los Santos, B. (2012). First Report of Root and Crown Rot Caused by Pestalotiopsis clavispora (Neopestalotiopsis clavispora) on Strawberry in Spain. *APS Publications*, 1495.

Chandler, C. (2009). *United States Patent No. USOOPP20363P2.*

Cheng, G. W., & Breen, P. J. (1992). Cell count and size in relation to fruit size among strawberry cultivars. *J. Amer. Soc. Hort. Sci.*, 117, 946-950.

DADO. (2017). Annual report. Nuwakot.

Dale, A., Walker, G., & Fisher, P. (2000). Growing strawberries in Ontario. *Ontario Ministry of Agriculture,*
Food and Rural Affairs.

Darnell, L. R. (2003). Strawberry growth and development. In: N. F. Childers (ed.), The strawberry: A book for Growers, Gainesville, FL: Children Publications.

Darrow, G. M. (1966). The strawberry. New York: Holt Rinehart and Winston.

Das, A. K., Singh, K. P., Prasad, B., & Ravindra, K. (2015). Evaluation of cultivars of strawberry, a temperate fruit for its adaptability as well as productivity in subtropical agro-climatic condition of Supaul district in Bihar. Asian J. Hort, 10(2), 278-281.

Day, D. (1993). Strawberries. Grower Digest Series No. 3. London: Nexus Business Communications.

Embaby, E. M. (2007). Pestalotia fruit rot on strawberry plants in Egypt. Egypt J. Phytopathol, 35, 99-110.

FAO. (2019). FAOSTAT statistical database. Rome.

Girijalba, C. M., Perez-Trujillo, M. M., Ruiz, D., & Ferrucho, A. M. (2015). Strawberry yields with high-tunnel and open-field cultivations and the relationship with vegetative and reproductive plant characteristics. Agronomia Colombiana, 33(2), 147-154. doi:10.15446/agron.colomb.v33n2.52000

Guttridge, C. G. (1979). Anther failure main cause of poor fruit set in Redgauntlet [strawberry]. Grower, 91, 38-39.

Hancock, J. F. (1999). Strawberries. New York: CABI publish.

Hellman, E. W., & Travis, J. D. (1988). Growth inhibition of strawberry at high temperatures. Adv. Strawberry Prod, 36-38.

Jami, Y. Y., Sarkar, A., & Maiti, C. S. (2015). Evaluation of strawberry cultivars in the foothills of Nagaland. Journal Crop and Weed, 11(special issue), 198-200.

Joolka, N., & Badiyala, S. D. (1983). Studies on the comparative performance of strawberry cultivars. Haryana J.of Hort.sci, 12(3-4), 173-177.

Klimczak, A., & Stropek, M. (1988). Evaluation of the yield of six strawberry varieties in Southeast Poland. Ocenaplonowania szyscinomian truskawek W warunkach Polski południowo-wschodniej, 28, 31-35.

Kurian, A. (2015). Thesis on “Performance of strawberry (Fragaria ananassa Duch.) in different growing conditions”. Kerala, India.

Ledesma, N. A., Nakata, M., & Sugiyama, N. (2008). Effect of high temperature stress on the reproductive growth of strawberry cvs. „Nyoho” and „Toyonoka. Scientia. Hort, 116, 186-193.

Menzel, C., & Smith, L. (2010). Runner quality. In Strawberry Reproductive and Development, 6-15. Queensland: Queensland Government.

Nepali Times. (2017, Jan 5). Strawberry mountains. http://archive.nepalitimes.com/article/nation/strawberry-mountains-nepal,3437

Nitsch, J. P. (1950). Growth and morphogenesis of the strawberry as related to auxin. Amer. J. Bot, 37, 211-215.

Okimura, M., & Igarashi, I. (1997). Effects of photoperiod and temperature on flowering in everbearing strawberries. J. Amer. Soc. Hort. Sci, 872-880.

Perkins-veazie, P. (1995). Growth and ripening of strawberry fruit. Horticultural Reviews, 17.

Poling, E. B. (2002). Strawberry Plant Structure and Growth Habit. New York: NC State University.

Rahman, M., Hossain, M., Khaleque, M., & Khalid, Q. A. (2013). Characterization and field performance of 15 Strawberry germplasm under Bangladesh conditions. SAARC J. Agr, 11(2), 81-94.

Renquist, A. R., Breen, P. J., & Martin, L. W. (1982). Influences of water status and temperature on leaf elongation in strawberry. Scientia Hort, 18, 77-85.

Sato, N., & Hiraoka, T. (1971). Study on temperature and management in forcing strawberry. I. Effect of heating soil and air on the growth and yield of forcing strawberry. Bull. Kanagawa Hort. Exp. Sta, 19, 76-81.

Shaw, D. V. (1990). Response to selection and associated changes in genetic variance for soluble solids and titratable acids contents in strawberries. J.Amer.Soc. Hort.Sci, 115, 839-843.

Singh, R., Sharma, R. R., & Goyal, R. K. (2007). Interactive effects of planting time and mulching on ‘Chandler’ strawberry (Fragaria ananassa Duch.). Sci.Horti, 111, 344-351.

Stewart, P., & Folta, K. (2010). A review of photoperiodic flowering research in strawberry (Fragaria spp.). Critical Reviews in Plant Sciences, 29(1), 1-13.

Strik, B. C. (1988). Photosynthesis, yield component analysis, and growth analysis of strawberry. Dissertation-Abstracts-International. B-Science-and-Engineering, 48(8), 2175.

Tanaka, Y., & Muzata, M. (1974). Nutritional – physiological studies on strawberry cv. Hokowase in long term cultivation I. Influence of nitrogen on growth, yield and absorption of nutrients. Bul.Nara. Agri.Expt.Sta, 38-43.

TEPC. (2019). Import database Nepal.

Wani, M. S., Rather, B. A., Sharma, M. K., & Singh, S. R. (2007). Effect of different planting time and mulches on flowering, yield and quality of strawberry. The Hort J, 20, 5-7.

Went, F. (1957). The experimental control of plant growth. Cronica Botanica, 17.

Whitaker, V. M., Chandler, C. K., & Peres, N. A. (2015). Sensation™ Florida127™ Strawberry. HortScience, 50(7), 1088-1091.

Whitaker, V. M., Chandler, C. K., & Peres, N. A. (2017). Sensation™ Brand Florida127™ Strawberry. Florida: Horticultural Sciences Department, UF/IFAS Extension.

Whitaker, V. M., Peres, N. A., & Agehera, S. (2017a). Florida Beauty™ Strawberry. Florida: Horticultural Sciences Department, UF/IFAS Extension.

Whitaker, V. M., Chandler, C. K., Santos, B. M., & Peres, N. A. (2019). Florida Radiance™ Strawberry. Florida: Horticultural Sciences Department, UF/IFAS Extension.