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Physiological performance of selected strawberry (*Fragaria x ananassa* Duch) as influenced by varying levels of nitrogen fertilizers

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Abstract The result revealed that San Andreas cultivars prevailed on the physiological response like relative chlorophyll content while Honeoye variety gave a better in partitioning coefficient and dry matter yield. San Andreas prevailed in fruit and fruit yield aspect where it accumulated 12.53 in average fruit weight. San Andreas also dominated with 18.84 in weight of marketable fruit, total yield with 21.16, and an ROI of 16.78. T5 (RR + 100% N) was the highest ROI with 18.53 followed by T3 (RR + 50% N) with 16.25, T4 (RR + 75% N) with 15.29, T2 (RR + 25% N) with 12.40 and T1 (RR N) with 10.77, respectively. There was significantly identified on interaction between variety and nitrogen levels where it showed 14.65 result on the ROI. San Andreas variety in strawberry production in Claveria which is found to be favorable to the variety based on the relative chlorophyll content and its bigger yield compared to Honeoye.

Keywords: Physiological responses, Honeoye, Nitrogen levels, San Andreas, Strawberry

Introduction

Strawberry production is a fascinating aspect of agriculture that involves the cultivation of the beloved and delectable fruit, the strawberry (*Fragaria* × *ananassa*). It is a process that requires careful attention to various factors, including climate, soil conditions, varieties, and farm practices like application of fertilizers. Strawberries are grown on all continents, from tropical areas to sub-arctic climates showing the capability of the species to adapt to different environments (Hytönen and Kurokura, 2020). The United States was the primary producer of strawberries imported by other nations and accounted for 4.6 million tons of the high-value crop's global production in 2012 (Vergara *et al.,* 2018). In the Philippines, local strawberry production increased by an average of 5.16 percent annually. The peak was 842 metric tons in 2018, and the lowest was 762 metrictons in 2016. Eight hundred seven (807) metric tons were considered the

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average production (Philippine Statistics Authority, 2019). The production of strawberry was supported by different macro and micro elements which sustains its growth and development. Of all the essential nutrients needed for strawberry cultivation, nitrogen (N) stands out as it promotes vigorous plant growth, thus resulting in a high yield (Preciado-Rangel *et al.,* 2020).

Strawberry production is possible in areas of the country with a cooler climate like Claveria, Misamis Oriental. Previous research showed that in Claveria conditions, the Japanese strawberry variety produced a significant number of runners and marketable fruits (Taylaran *et al.,* 2011). However, limited information is available regarding the use of different varieties of strawberries in Claveria, Misamis Oriental. The combination of environment and fertilization factors affects the growth of the strawberry. Thus, this study aimed to provide information for suitable varieties applied with varying levels of nitrogen fertilizer, which can provide high yield under Claveria, Misamis Oriental conditions.

Materials and methods

Location of the study

The study was conducted at the experimental field area of the Research Office of the University of Science and Technology of Southern Philippines – Claveria Campus (8.6788° N, 124.9727° E), Claveria, Misamis Oriental, Philippines. It was conducted from November 2022 to March 2023.

Agro-climatic condition

The agro-climatic condition was identified based on the accumulated results of temperature and total rainfall from the start of the study to the end of the implementation (November 2022 – March 2023). Climate can affect the growth and yield production of strawberry cultivars. Ledesma *et al.* (2008) stated that high-temperature stress negatively affects the reproductive process in strawberries.

Experimental design and treatments

A pot experiment was conducted and laid out in a two fators factorial experiment in Randomized Complete Block Design (RCBD) with two varieties, five nitrogen levels, and replicated three times. The selected strawberry varieties are V1 (Honeoye) and V2 (San Andreas) and applied with different levels of nitrogen fertilizer namely: T1 (RR N), T2 (RR + 25% N), T3 (RR + 50% N), T4

(RR + 75% N), and T5 (RR + 100%). A total of 300 plants were identified and every treatment per variety has 10 sample plants with 14 cm x 20 cm plant pots.

Cultural practices

Cultural practices were also conducted with the following activities: Pot and mixture preparation, where the soil media mixture was prepared using the following media: garden soil, carbonized rice hull, organic fertilizer (Well Grow), and coco coir. The ratio was 1:1:1:1 and mixed thoroughly before placing it in a planting pot; planting seedlings in prepared pots; labeling sample plants for identification and data gathering; fertilizer application was performed one week after planting and applied depending on the recommended percentage per treatment; pest and disease management if necessary; and harvesting strawberries if the fruit is at the right stage of maturity. Based on the Philippine National Standards (2014), when berries are 75% or more red, they are harvested. Fruits are manually selected by pinning the stalk forward, and then they are immediately put into a Styrofoam container with three compartments to help with sorting Philippine National Standards (2018).

Data gathered

Physiological parameters were gathered such as the Relative Chlorophyll Content (RCC), Using the SPAD meter, fully expanded leaves of the main strawberry plant were used to measure the relative chlorophyll content and recorded as a mean of the three measurements of each selected individual leaf. This parameter was collected one week after planting with a one-week interval until termination of the study.

Partitioning Coefficient (PC) were also gathered segregating the parts such as stem, leaves, and roots. Dry Matter Yield (DMY) were also recorded by selecting uprooted plants per treatment from the ground and weighed fresh, and air dried under ambient conditions. Air dried plants will be subjected to oven dry 80°C for 48 hours. Yield responses were also identified such as average fruit weight (g/plant), weight of marketable and non-marketable fruit (t/ha), Total yield (t/ha) and Return on Investment (ROI)

Statistical analysis

The data were run by SPSS software and analyzed using the analysis of variance (ANOVA) and the Tukey's test (HSD) at 5% was used to test the differences among treatment means.

Results

Agro-climatic data

For the period from November 2022 to February 2023, the maximum temperature recorded was on the month of November and March at 29°C while the month of January got the lowest maximum temperature at 27°C and average temperature at 24°C. The month of March obtained the highest average temperature at 26°C.

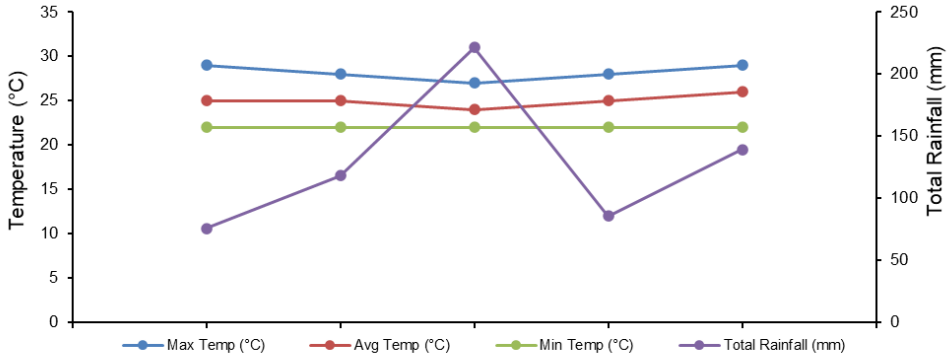

Figure 1. Agro-climatic condition of Claveria, Misamis Oriental for the period November 2022 to March 2023

Moreover, a 22°C minimum temperature was observed for the whole duration of the study. Data shows that the highest amount of rainfall were recorded on the month of January 2023 with 221.30 mm, followed by March 2023 with 139.2 mm, and December 2022 with 118.2 mm, February 2023 with 85.55 mm, and November 2022 with the lowest amount of total rainfall at 75.70 mm.

Relative chlorophyll content (RCC)

The results showed that factor between varieties showed mix result from seven DAP to 84-DAP. San Andreas was highly significant resulted between Honeoye from seven DAP to 28-DAP with 38.15 to 40.13 while Honeoye had only 35.36 – 37.84 (Table 1). There was not significantly differed between varieties at 35-DAP to 56-DAP followed by 63-DAP where San Andreas was 40.24 while Honeoye was 38.43. The following DAP was high significantly differed where San Andreas was 38.03 – 41.42 while Honeoye had only 35.90 –

37.84. Between varieties, San Andreas prevailed the chlorophyll content was the highest mean of 41.42 while Honeoye was 38.43. All the nitrogen levels increased the mean of their Relative Chlorophyl Content from 14-DAP to 21-DAP followed by an alternate decreasing and increasing from 28-DAP to 56-DAP. The result increased from 63-DAP to 70-DAP to all nitrogen levels.

Table 1. Relative Chlorophyll Content (RCC) of selected strawberry varieties at 7 DAP to 84 DAP as influenced by varying levels of nitrogen fertilizer

TREATMENTS	RELATIVE CHLOROPHYLL CONTENT											
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP	56 DAP	63 DAP	70 DAP	77 DAP	84 DAP
Factor A (Varieties)												
Honeoye	37.50 b	37.67 b	37.84 b	35.36 b	37.28	37.21	37.69	38.06	38.43 b	37.84 b	35.90 b	35.99 b
San Andreas	39.78 a	39.96 a	40.13 a	38.15 a	39.30	38.66	38.15	39.20	40.24 a	41.42 a	38.03 a	39.60 a
F-test	**	**	**	**	ns	ns	ns	ns	*	**	**	**
Factor B (N Levels)												
T_1 – RR N	39.75	38.97	39.97	37.82	39.94	38.47	38.77	38.80	38.93	39.17	36.28	37.65
T_2 – RR + 25% N	37.75	39.22	39.23	35.61	37.00	37.09	36.56	37.74	38.92	39.93	37.62	37.78
T_3 – RR + 50% N	38.48	38.85	39.21	37.00	38.32	38.25	40.22	40.49	40.76	39.19	36.40	38.16
T_4 – RR + 75% N	38.19	38.73	39.26	36.97	38.43	36.98	37.75	38.67	39.58	39.66	37.04	37.21
T_5 – RR + 100% N	39.03	39.17	39.25	36.37	37.77	37.87	38.59	39.53	38.48	40.19	37.48	38.20
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Variety x N Levels	38.64	38.82	38.99	36.75	38.29	37.93	38.92	38.78	39.33	39.63	36.96	37.80
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C.V %	4.73	4.15	4.16	6.07	7.58	6.71	7.14	6.98	4.40	6.60	5.56	6.96

Means in a column followed by a common letter are not significantly different at 5% level using Tukey's test, ** Significant at a level of 1% of probability ($p \leq 0.01$), * Significant at a level of 5% of probability ($p \leq 0.05$), ns - non-significant ($p > 0.05$), DAP - Days After Planting

The highest mean RCC was recorded at 63-DAP garnered by T3 (RR + 50% N) with 40.76 followed by the same treatment at 56-DAP and 49-DAP with 40.49 and 40.22, respectively. The interaction between variety and nitrogen levels was a highest mean of 38.63 at 70-DAP and not significantly differed.

Partitioning coefficient of roots, stem, and leaves

It showed the partitioning coefficient of roots, stem, and leaves of selected strawberry varieties applied with varying levels of nitrogen fertilizer were collected at one MAP, two MAP, and three MAP (Table 2). All of the cultivars increased the partitioning coefficient of stem at two MAP and decrease both varieties at three MAP. Honeoye was the highest mean between varieties with highest partitioning of the following: partitioning of roots with 30.15 at two MAP, partitioning of stem with 33.38 at two MAP, and partitioning of leaves with 46.35 at three MAP.

Table 2. Partitioning coefficient of roots, stem and leaves of selected strawberry varieties at 1 MAP, 2 MAP, and 3 MAP as influenced by varying levels of nitrogen fertilizer

TREATMENTS	PARTITIONING COEFFICIENT, (%)								
	1-MAP			2-MAP			3-MAP		
	Roots	Stem	Leaves	Roots	Stem	Leaves	Roots	Stem	Leaves
Factor A (Varieties)									
Honeoye	29.58[a]	29.20[a]	46.29	30.15[a]	33.38	40.66	27.46	28.41	46.35
San Andreas	24.51[b]	24.51[b]	45.90	25.96[b]	30.47	39.38	27.38	26.27	44.13
F-test	*	**	ns	*	ns	ns	ns	ns	ns
Factor B (N Levels)									
T_1 – RR N	28.05	26.98	44.97[ab]	28.77	33.61	37.32	28.38	26.18	45.44
T_2 – RR + 25% N	26.78	26.68	46.45[ab]	28.24	30.41	41.35	28.38	24.40	47.22
T_3 – RR + 50% N	28.45	26.64	44.91[ab]	29.41	32.19	38.41	26.66	28.68	44.66
T_4 – RR + 75% N	27.49	28.02	44.96[b]	27.50	32.82	39.68	26.02	29.01	44.97
T_5 – RR + 100% N	24.45	25.97	49.57[a]	26.35	30.59	43.05	27.66	28.44	43.66
F-test	ns	ns	*	ns	ns	ns	ns	ns	ns
Variety x N Levels	27.04	26.86	46.09	28.05	31.92	40.02	27.42	27.34	45.24
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns
C.V %	18.40	17.90	8.42	19.37	20.17	20.23	13.60	18.92	9.49

Means in a column followed by a common letter are not significantly different at 5% level using Tukey's test, ** Significant at a level of 1% of probability ($p \leq 0.01$),* Significant at a level of 5% of probability ($p \leq 0.05$), ns - non-significant ($p > 0.05$), MAP - Month After Planting

San Andreas showed a good result where partitioning coefficient of roots with 27.38 at three MAP, partitioning coefficient of steam with 30.47 at two MAP and partitioning coefficient of leaves with 45.90 at one MAP. Significant difference between cultivars were also identified at one MAP and two MAP where Honeoye dominated the partitioning of roots at one MAP and two MAP and partitioning coefficient of stem at one MAP. Other parts of the plant in different months showed that Honeoye had more percentage in each part than

San Andreas cultivar, but it was not significantly differed. Nitrogen levels were identified in Table 2 where it revealed that there was significantly differed in partitioning coefficient of leaves at one MAP. T5 dominated the partitioning of leaves with 49.57 followed by T2 with 46.45, T1 with 44.97, T4 with 44.96, and T3 with 44.91. Other parts in different months applied with different nitrogen levels as well as the interaction between factors was not significantly differed.

Dry matter yield

It showed that dry matter yield of selected strawberry cultivars as influenced by varying levels of nitrogen fertilizer. Honeoye dominated all the months between varieties where it was highest resulted of 52.50 at three MAP while San Andreas was 51.46 at the same month All of the cultivars increased the dry matter yield at two MAP to three MAP (Table 3).

Table 3. Dry matter yield of selected strawberry varieties at 1 MAP, 2 MAP, and 3 MAP as influenced by varying levels of nitrogen fertilizer

TREATMENTS	DRY MATTER YIELD, g		
	1 MAP	2 MAP	3 MAP
Factor A (Varieties)			
Honeoye	21.65[a]	23.31	52.50
San Andreas	20.28[b]	21.67	51.46
F-test	*	ns	ns
Factor B (N Levels)			
T_1 – RR N	20.38	23.48	54.12[a]
T_2 – RR + 25% N	23.78	24.31	54.39[a]
T_3 – RR + 50% N	20.67	22.46	55.32[a]
T_4 – RR + 75% N	20.94	21.51	44.35[b]
T_5 – RR + 100% N	19.06	23.71	51.73[ab]
F-test	ns	ns	*
Variety x N Levels	20.96	22.49	51.98
F-test	ns	ns	ns
C.V %	17.59	19.47	12.42

Means in a column followed by a common letter are not significantly different at 5% level using Tukey's test
* Significant at a level of 5% of probability ($p \leq 0.05$) and
MAP - Month After Planting

Honeoye showed a better result than San Andreas variety and it revealed that there was significantly differed between the two in the first month. Same pattern where also revealed in different levels of nitrogen and the interaction between the two factors. All of the nitrogen levels increased their partitioned stem at two MAP to three MAP. T3 (RR + 50% N) was the highest partitioning coefficient of with 55.32 at three MAP followed by T2 (RR + 25% N) with 54.39,

T1 (RR N) with 54.12, T5 (RR + 100% N) with 51.73, and T4 (RR + 75% N) with 44.35 at the same month, respectively. The highest mean recorded in the interaction between factor at three MAP with 51.98 followed by 22.49 at one MAP, and 20.96 at one MAP. Factor B and the interaction between variety and nitrogen levels were not significantly differed.

Yield parameters

Average fruit weight, weight of marketable and non-marketable fruit and ROI of selected strawberry varieties were influenced by varying levels of nitrogen fertilizer (Table 4).

Table 4. Average fruit weight per plant, weight of marketable and non-marketable fruit, and ROI of selected strawberry varieties as influenced by varying levels of nitrogen fertilizer

TREATMENTS	FRUIT YIELD				
	Average Fruit Weight (g/plant)	**Weight of Marketable Fruit (t ha^{-1})**	**Weight of Non-Marketable Fruit (t ha^{-1})**	**Total Yield (t ha^{-1})**	**ROI (%)**
Factor A (Varieties)					
Honeoye	11.16^{b}	16.63^{b}	1.74^{b}	18.37^{b}	12.51^{b}
San Andreas	12.54^{a}	18.84^{a}	2.31^{a}	21.16^{a}	16.78^{a}
F-test	**	*	**	*	**
Factor B (N Levels)					
T_1 – RR N	11.45	17.14	1.88	19.01	10.77^{c}
T_2 – RR + 25% N	11.73	17.37	1.93	19.30	12.40^{c}
T_3 – RR + 50% N	12.01	17.99	2.12	20.11	16.25^{b}
T_4 – RR + 75% N	11.86	17.85	2.07	19.92	15.29^{b}
T_5 – RR + 100% N	12.22	18.35	2.12	20.48	18.53^{a}
F-test	ns	ns	ns	ns	**
Variety x N Levels	11.85	17.74	2.02	19.76	14.65
F-test	ns	ns	ns	ns	*
C.V %	12.17	14.73	18.64	15.24	17.92

Means in a column followed by a common letter are not significantly different at 5% level using Tukey's test, ** Significant at a level of 1% of probability ($p \leq 0.01$,),* Significant at a level of 5% of probability ($p \leq 0.05$), ns - non-significant ($p > 0.05$)

San Andreas prevails in fruit and fruit yield aspect accumulated 12.53 in average fruit weight. San Andreas dominated with 18.84 in weight of marketable fruit, total yield with 21.16, and an ROI of 16.78. San Andreas showed better

result than Honeoye and there was not significantly differed to all of the categories. San Andreas was the highest result of 2.31 in non-marketable fruit compared to Honeoye variety with 1.74. T5 (RR + 100% N) which was the highest ROI with 18.53 followed by T3 (RR + 50% N) with 16.25, T4 (RR + 75% N) with 15.29, T2 (RR + 25% N) with 12.40 and T1 (RR N) with 10.77. There was significantly differed on interaction between variety and nitrogen levels showing 14.65 on the ROI.

Discussion

Based on the results of Lalk *et al.* (2023), San Andreas variety garnered higher SPAD with 37.5 while Honeoye variety was 35.3 and San Andreas was the highest SPAD among the different varieties being tested. Chlorophyll is a crucial component that helps plants absorb, distribute, and transform light energy and is crucial to produce yields (Siddique *et al.,* 2021).

In the partitioning coefficient of strawberry, the results were the same with Park where June bearing strawberries such as Honeoye is more on vegetative production compared to everbearing varieties of strawberry (Park *et al.,* 2023). Tei *et al.* (2002) observed that dry matter yield can be affected starting from partitioning and partitioning can be affected by nitrogen fertilization observing higher partitioning towards plant at lower nitrogen rate compared to higher nitrogen levels. Mohamed *et al.* (2021) coined that nitrogen levels can either have higher dry matter yield or lower dry matter yield compared to other levels because of the fresh weight affected by environmental factors.

In yield performance, Guan *et al*. (2022) observed that San Andreas variety has the highest average fruit weight compared to other varieties from different types of strawberry (short day strawberries and day neutral strawberries). Lalk *et al.* (2023) concluded that San Andreas has an average fruit weight of 17.8 g while Honeoye has an average of 10.1 which gives San Andreas is heavier than Honeoye. Lalk *et al.* (2023) and Guan *et al.* (2022) also emphasized that San Andreas has greater yield compared to short day neutral plants such as Honeoye variety. Based on the study of Khatun *et al.* (2020), the average yield of strawberry is 20.80 t ha-^{1} which is close to the average result. Study of de Lima *et al.* (2021) stated that the result of non-marketable fruit is discarded because of fungi or pest attacks which makes the fruits to be commercialized. Environmental factors such temperature and photoperiod can directly affect the fruit and also the fruit yield (Ahn *et al.,* 2021). On the other factors, all of the categories show a no significant difference to different levels of nitrogen fertilizer except of the ROI with highly significant result. Based on the study of Cantliffe and Castellano (2007), there was no significant difference between the recommended rate of

nitrogen to higher levels of nitrogen in both marketable yield and total yield. The interaction between nitrogen levels and strawberry variety affects the return on investment of strawberry because of the nutrients provide by the nitrogen affecting the number of fruits of each levels (Agehara and Nunes 2021).

The study revealed that Honeoye dominated between the selected varieties in agronomic parameters such as number of leaves, number of runners, number of daughter plants, and number of flowers. Honeoye showed longer in San Andreas in terms of root length, but it was not significantly differed at all. In the other factors like the levels of nitrogen fertilizer and the interaction between varieties and nitrogen levels, there were not significantly differed. San Andreas showed a best result in terms of relative chlorophyll content while Honeoye showed a best result in the partitioning coefficient of leaves. The other components of physiological responses like partitioning coefficient of leaves and stem, and dry matter yield showed significant result. Other components of physiological responses like partitioning coefficient of leaves did not significantly differed between varieties, but it was significantly differed in nitrogen where T5 dominated. San Andreas variety in strawberry production in Claveria which is found to be favorable to the variety based on the relative chlorophyll content and its bigger yield compared to Honeoye.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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