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RESEARCH ARTICLE

Effects of Planting Dates, Chilling Periods and Foliar Spray with N/P Ratio on Growth Characteristics of Strawberry (Fragaria x ananassa.) cv. Robygem under Hydroponic Conditions

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ABSTRACT

This study was carried out in unheated green house during growing season 2022 and 2023 in Malta Forest Nursery of the General Directorate of Forests and rangeland located in Duhok city, Duhok governorate, Kurdistan region/ Iraq to investigate the effect of planting dates, chilling days and foliar application (nitrogen and phosphorous) and their interactions on the vegetative growth properties of strawberry plant cv. Rubygem. The results indicated that optimal strawberry growth was on September 15th which recorded highest value of crown diameter (17.521 and 17.342) mm, highest root dry matter (11.72 and 10.762 g), vegetative dry matter (19.213 and 16.224 g) and highest leaf area per plant (106.4 and 102.94 cm2 /plant) respectively in both growing seasons. October 1st obtained highest chlorophyll content (41.446 and 40.81 µg.m2-1) in two growing season. N/P Ratio: 100/100 treatment ratio provided an ideal nutrient balance that enhanced all the measured traits in the study. Chilling plants for 10 days considered effective. The bilateral and triple interactions had significant effects.

INTRODUCTION

Strawberry *(Fragaria X ananasa* Duch.*)* is the most refreshing and delicious refreshing fruit crop in the "Rosacea" family. It has subtle flavors and is high in vitamins and minerals (Sharma and Yamdagni 2000; Sharma, 2000). Additionally, it has a larger concentration of other ingredients including flavonoids and phenolic (Häkkinen and Törrönen, 2000). As it is non-climacteric, it only reaches maturity on plants (Cordenunsi *et al*., 2003). Cold storage effectively preserves strawberry quality, storing strawberries at 16 °C strikes a balance between maintaining their sensory attributes and nutritional values across all cultivars (Cordenunsi *et al*., 2005). This temperature appears to offer an optimal compromise, preserving the strawberries' taste, texture, and health benefits. Because strawberries grow well in different conditions, they can be grown anywhere from the arctic to the tropics (Barney, 1999; Ayesha *et al*., 2011). Strawberries that are cultivated are native to North America and date back to the early 1700s in Europe. The United States is the largest producer of strawberries (1.164 million tons) (FAO 2020). There are around 1,000 varieties of strawberries, with 125 varieties cultivated commercially worldwide (Al-Baiati, 2011; Al-Ibrahim, 2002; Al-Saidi, 2000). The optimal temperature for vegetative growth is between 20 and 22 ^{0}C. Temperature for flowers is 15-17 ^{0}C (Al-Saidi, 2000). Recently, the consumption of strawberries as fresh fruit has risen due to their appealing appearance, delicious taste, and high nutritional value. Additionally, strawberries are used in various industries for products like juice, jam and candy. Strawberries possess medicinal and therapeutic benefits; researchers have found that consuming eight strawberries a day can promote a healthy heart and lower blood pressure (Chandler, 2000). The growing demand has led to the adoption of modern strawberry production methods, such as soilless cultivation or hydroponic systems, replacing traditional methods. One of the key success factors in using soilless cultivation systems is the management of nutrient solutions and substrates (Firoozabadi, *et al*., 2009; Por-Hossein *et al*., 2009). Greenhouse production leads to higher yields, extends the growing season, and improves pest control. This approach reduces the need for chemicals, which can enhance the quality of the fruits (Dinar, 2003). Strawberry, has been considered a model plant system for Rosaceae, and is susceptible to a large variety of phytopathogenic organisms (Amil-Ruiz *et al*., 2011).

Several factors affect strawberry cultivation, including transplanting date, fertilization, irrigation, and more. However, in Iraq and Kurdistan, strawberry cultivation is relatively recent and not extensively studied, with only a few research efforts covering limited factors. Therefore, further research is needed to enhance the growth and yield of this crop, particularly in areas such as hydroponic cultivation, culture media and transplanting dates (Dawood, 2009). Environmental conditions are crucial in determining the earliness, fruit quality, and overall yield of strawberries. The planting date is essential for successful strawberry production (D'Anna *et al*., 2002). Temperature, daylight, and photoperiod directly influence transplanting time, which in turn affects flowering, fruit size, and yield (Wilkins, 1984). The predominant climatic conditions at the time of planting and next period of plant growth might affect the vegetative growth of strawberry plants (Bhamini, 2017). The timing of planting is crucial for optimizing flower and fruit production (Dawood, 2009).

One of the key factors influencing the successful growth and yield of strawberries is the chilling requirement. In temperate regions, strawberry plants gather a sufficient number of chilling hours (CHs) and store carbohydrates in their roots and crowns. Meanwhile, the shoots stay dormant in response to the short daylight periods and low temperatures during the autumn and winter months, On the other hand, the chilling requirement is crucial for the initiation of strawberry flowers. Adequate cold conditioning or exposure to chilling during late autumn and winter enables strawberry plants to adapt and thrive in temperate regions (Durner, *et al*., 1984; Maas, 1986). Meanwhile, inadequate chilling results in low vegetative vigor and reduced vegetative growth, flowering, and fruiting of strawberry (Tulipani, *et al*., 2011; Craig and Brown, 1977; Robert, *et al*., 1997; Crandall, *et al*., 1990). Dawood, (2008) indicated that foliar spray of Fe-EDTA had a significant effect on most growth and yield characteristics of the plants especially when applied on first date March 15th and significantly improved leaf area, number of runners per plant, dry weight of vegetative growth, total chlorophyll content, number of fruits per plant, average yield per plant and per unit area, total soluble solids, and vitamin C content compared to the control treatment. Chilled plants with large crown diameters treated with GA had the largest leaf area and highest leaf number (Khalil, 2016).

In strawberry (Fragaria × ananassa Duch.) cultivation, nitrogen N is one of the most crucial nutrients for promoting vigorous plant growth (Monroy, *et al*., 2002), thereby enabling high yields (Cardeñosa, *et al*., 2015). However, proper management of nitrogen nutrition is essential. When nitrogen levels are adequate, the production of nitrogen-containing compounds, such as amino acids, proteins, and alkaloids, is optimized (Sharma *et al*., 2008; Sharma and Goyal, 2007).

Regarding phosphorus P, an essential nutrient for crop propagation, health, and vigor (Li and Hu, 2010), strawberry plants exhibit intensified dark green leaf coloration under deficiency. This occurs due to a reduction in the leaf blade area, resulting in a higher concentration of chlorophyll per unit area (EPAMIG, 2007). Insufficient phosphorus P nutrition leads to slowed branch development, reduced stem elongation, and decreased ability to withstand extreme weather conditions and pathogen-induced stress (Choi *et al*., 2013).

MATERIAL AND METHODS

The experiment is included three factors, the first factor is planting dates 15/9, 1/10 and 15/10, the second one is subject the transplants to three periods of cooling ($4 \pm 1^{o}C$), 0, 10 and 20 days before planting, and the third factor is plants spray with N and P (100:100 mg. L^{-1}) as urea $CO(NH_2)_2$ and Phosphorus pentoxide P_2O_5 forms at three times (beginning of each of growth started, flowering started and fruiting started).

Adjusted cooper nutrition solution at full strength was used in this experiment. The culture media used was washed and sterilized building sand, continuous sterilization at periods and some stones putted below pots before sand. The 20 cm sized in diameter of pots used with irrigation system (drip irrigation) with two drippers for each pot. The culture distance 25*25 cm. The transplants of Robygem cultivar obtained from privet nursery as runner plants, homogenous in growth, crown diameter and vigor, were dipped in fungicide for 10 minutes, remained leaves conjoined before planting and runners removed every week. The pH and EC of solution and drained water calculated and adjusted every week by KOH and phosphoric acid H_3PO_4 and the solution renewed every 15 days. The experimental units arranged as Split-Split Plot experiment 3*2*3 in RCBD, with 5 plants for each experimental units and four replication 360 plant, where the planting date putted in main plots, chilling periods in sub plots and the N and P spray in sub-sub plots,the treatment means comparisons by Duncan Multiple Range Test at significant level 5%, and the data analyzed by SAS program.

The experimental measurements were as follows

1. Total chlorophyll

At the end of season average of leaves greenness was taken from leaves of each plant of each replicate by using chlorophyll meter (SPAD-502; Minolta, Osaka, Japan).

2. Crown diameter (mm)

The average of crowns diameters was determined by using electronic Venire caliper equipment, and the measurements were taken then the averages were calculated.

3. Root dry matter (%)

The percentage of rot dry matter was measured for the selected plants at the end of season by weighting the fresh roots then dried in an oven at 70°C for 72 hours and average and the dry matter percentage was calculated according to the following equation:

$$\text{Dry matter (\%)} = \frac{\text{Weight of dry sample}}{\text{Weight of fresh sample}} \times 100$$

4. Vegetative dry matter (%)

The soft weight of the vegetative for four plants was taken from each experimental unit and then dried in an oven at 70°C until the weight was stable then weighed and the vegetative dry matter percentage was calculated according to the following

$$\text{Dry matter (\%)} = \frac{\text{Weight of dry sample}}{\text{Weight of fresh sample}} \times 100$$

5. Leaf area (cm^2 /plant).

Three full expanded leaves were taken from each plant and four plants from each treatment after harvest all fruits, to determine leaf area by roles according to Abdel, (1994).

$$\text{Estimated leaf area} = \text{length} \times \text{width} \times 0.75$$

RESULTS & DISCUSSION

1. Total chlorophyll ($\mu g.m^{2-1}$)

Data in table (1) revealed that during the first and second season, planting on 1st October yielded significantly higher chlorophyll SPAD values (41.446 and 40.817 $\mu g.m^{2-1}$) respectively in both growing seasons. Mean effect of chilling showed no significant effect for both seasons, highest value obtained from 0 chilling in both years (40.53 and 40.194 $\mu g.m^{2-1}$) respectively. Concerning the effect of N/P ratio it was appeared that there were significant effect observed in plant treated with 100/100 which recorded maximum value in first and second seasons (40.491 and 42.03 $\mu g.m^{2-1}$) respectively compared with no N/P treat.

Concerning to the bilateral interaction between planting time and chilling, the effects were significant, in the first and second seasons, the highest means of chlorophyll were obtained from the interaction of second time 1st October with no chilling in 2022- and third-time 15th with chilling10 in 2023 which recorded the highest values (43.338 and 41.484 µg.m $^{2-1}$) respectively.

The interaction between the factors planting time*N/P ratio had a significant effect on chlorophyll content on 1st October with 100/100 N/P which recorded highest values in both years (41.501 and 44.348 µg.m$^{2-1}$) respectively.

The results in first season indicated that the interaction between chilling and N/P ratios showed significant difference between means values. Plants with 20 chilling period and 100/100 treated with N/P ratio record the highest value (40.944 µg.m$^{2-1}$) in 2022. The interaction in the followed year recorded highest value (43.35 µg.m $^{2-1}$) in not chilling transplants treated with 100/100 N/P ratio.

Table 1: Effect of the planting dates, chilling, N/P ratio and their interactions on leaves chlorophyll content µg.m$^{2-1}$ of strawberry Rubygem cv.in 2022-2023

Time of Planting	Chilling of plants (4 ±1 ^{0}C)	N/P ratio 2022		N/P ratio 2023		Time*Cooling		Means of Time	
		0	100/100	0	100/100	2022	2023	2022	2023
15th Sep.	0	39.38 b-e	39.89 b-e	36.83cd	40.85a-d	39.64bcd	38.84 ab	39.05 b	37.32 b
	10	36.32 e	38.73 cde	36.85 cd	34.58 d	37.53 d	35.71 b		
	20	37.02 e	42.95 ab	34.79 d	40.03a-d	39.98 cd	37.41 ab		
1st Oct.	0	44.69 a	41.98abc	37.17cd	45.32 a	43.34 a	41.25 a	41.45 a	40.82 a
	10	38.03 de	41.39 a-d	38.15bcd	44.35 ab	39.71bcd	41.25 a		
	20	41.45 a-d	41.13 a-d	36.54 d	43.38abc	41.29 ab	39.96 ab		
15th Oct.	0	38.72 cde	38.52 cde	37.11 cd	43.88 ab	38.62 cd	40.49 a	38.91 b	40.22 a
	10	39.77 b-e	41.08 a-d	37.92bcd	45.05 a	40.42 bc	41.48 a		
	20	36.59 e	38.76cde	36.55 d	40.83a-d	37.68 d	38.69 ab		
Time* N/P ratio	15th Sep.	37.57 b	40.524 a	36.15 b	38.49 b	Means of Cooling			
	1st Oct.	41.39 a	41.50 a	37.29 b	44.35 a				
	15th Oct.	38.36 b	39.45 ab	37.19 b	43.26 a	2022	2023		
Chilling *N/P ratio	0	40.93 a	40.13 ab	37.04 b	43.35 a	40.53 a	40.19 a		
	10	38.04 c	40.40 a	37.64 b	41.33 a	39.22 a	39.48 a		
	20	38.35 bc	40.94 a	35.96 b	41.41 a	39.65 a	38.69 a		
Means of N/P		39.108 b	40.49 a	36.878 b	42.03 a				

Means of each factor and their interactions followed by different letters are significant by different from each other according to Duncan's multiple range test at 5%.

The interaction among the three experimental factors (Planting time. Chilling and N/P ratio) significantly affected on strawberry chlorophyll. The maximum chlorophyll content was obtained as a result of interaction among 1st October and controls (44.697 µg.m$^{2-1}$) in 2022. 15th October with second Chilling of Transplants (4 ±1 ^{0}C) and 100/100 N/P ratio recorded the maximum value of chlorophyll among three factors that gave (45.052 µg.m$^{2-1}$) in 2023 compared with the others interactions. The lowest value were recorded among combination the 15th September 10 days chilling and no N/P sprays (36.322 µg.m$^{2-1}$) in 2022 and first time of planting 20 days chilling of Transplants (4± 1^{0}C) and with no N/P ratio which gave lowest value (34.79 µg.m$^{2-1}$) in 2023.

2. Crown diameter (mm)

Data in (Table 2) displays the effect of the three factors on transplants crown diameter (mm). Planting date both 15th September and 1st October significantly effect on the crown diameter compared to 15th October which record the lowest value (16.895) mm in the first growing season, all dates not significantly affect the transplant diameter, where the highest value observed on 15th September (17.342) mm in second year.

Mean effect of chilling showed no significant effect in both years. Concerning the effect of N/P ratio it was appeared that there was significant effect recorded in plant with 100/100 treatment which recorded maximum value (17.469) and (17.633) respectively in first and second growing season.

Table 2: Effect of the planting dates, chilling, N/P ratio and their interactions on crown diameter (mm) of strawberry cv. Rubygem.in 2022-2023

Time of Planting	Chilling of plants (4 ±1⁰C)	N/P ratio				Time*Cooling		Means of Time	
		2022		2023					
		0	100/100	0	100/100	2022	2023	2022	2023
15thSep.	0	17.125 bc	17.38 abc	17.33 ab	17.25 ab	17.25 abc	17.29 a	17.52 a	17.34 a
	10	17.475 abc	18.5 a	16.9 ab	18 a	17.99 a	17.45 a		
	20	17 bc	17.65 abc	16.9 ab	17.68 ab	17.33 ab	17.29 a		
1thOct.	0	17.35 abc	17.7 abc	16.43 b	17.525 ab	17.53 ab	16.98 a	17.358 a	17.196 a
	10	17.225 bc	17.65 abc	16.88 ab	18.28 a	17.44 abc	17.58 a		
	20	16.475 c	17.75 ab	16.5 b	17.58 ab	17.11 bc	17.04 a		
15thOct.	0	17.4 abc	16.93 bc	16.25 b	17.28 ab	17.16 bc	16.76 a	16.89 b	16.91 a
	10	16.575 bc	17.2 bc	16.45 b	17.58 ab	16.89 bc	17.01 a		
	20	16.8 bc	16.48 c	16.38 b	17.55 ab	16.64 c	16.96 a		
Time* N/P ratio	15th Sep	17.2 bc	17.84 a	17.04 ab	17.64 a	Means of Cooling			
	1st Oct.	17.02 c	17.7 ab	16.6 b	17.79 a				
	15th Oct	16.93 c	16.87 c	16.36 b	17.47 a	2022	2023		
Chilling *N/P ratio	0	17.29 ab	17.33 ab	16.67 bc	17.35 ab	17.31 a	17.008 a		
	10	17.09 b	17.78 a	16.74 bc	17.95 a	17.44 a	17.36 a		
	20	16.76 b	17.29 ab	16.59 c	17.6 a	17.025 a	17.095 a		
Means of N/P		17.047 b	17.47a	16.667 b	17.63 a				

Means of each factor and their interactions followed by different letters are significant by different from each other according to Duncan's multiple range test at 5%.

Concerning to the bilateral interaction between time and cooling, the effects were significant in the first year obtained from the interaction first time of planting with chilling 10 days which recorded the highest value (17.988) mm. No significant effect occurs between means value in the second growing season where highest value (17.575) mm obtained from interaction between 1st October and chilling10.

The interaction between the factors time*N/P ratio had a significant effect on crown diameter, 15th September and 100/100 ratio had significant differences between mean values which obtained the highest value (17.842) in first year. All transplants with 100/100 ratio in the three dates had significant records between mean values compared with not sprayed, maximum value recorded on obtained on 1st October (17.792) for the second growing season.

The interaction between chilling and N/P ratio showed significant difference between mean values recorded the highest value in 10 and 100/100 (17.783) mm in season one, whereas 10 and 20 chilling period with 100/100 ratio were significant between all mean values in second year.

The interaction among the three experimental factors (Planting time *Chilling* N/P ratio) significantly affected on strawberry crown diameter. The maximum values were obtained as a result of interaction among 15th September and second Chilling of Transplants (4 ±1⁰C) with the 100/100 N/P ratio in first year (18.5) and second year (18), whereas recorded the maximum value among three factors in the second year obtained in 1st October 10 chilling and 100/100 ratio (18.275) compared with the others interactions, the lowest value were recorded among combination the second time of planting *Chilling of Transplants 20 and with no N/P ratio which gave lowest value (16.475) and third time 0 chilling and no N/P ratio gave value of 16.25.

3. Root dry matter (%)

(Table 3) data show that the planting date of September 15th significantly impacted root dry matter across both growing seasons, yielding the highest values of (11.72) g and (10.762) g, respectively. The lowest mean value was recorded on October 15th in the first and second year (10.142 and 9.958) g respectively.

The mean effect of chilling showed no significant impact; however, the highest values in both seasons were observed during the 10 days chilling period (10.945) g and (10.549) g respectively. The effect of the N/P ratio showed a significant impact, with plants having a 100/100 ratio recording values of (11.799) g and (11.783) g in both seasons compared to those with no N/P ratio.

The interaction between time and chilling showed significant effects observed on September 15th with 10 days chilling (12.235) g compared to other mean values, and for following year on October 1st with 20 days chilling (11.703) g. The interaction between the factors (Time*N/P ratio) had a significant effect on September 15th and 100/100 N/P compared to other interactions, recording (12.654) g in the first season. In the second season, three planting times with 100/100 N/P showed significant values compared to the no N/P ratio, with the highest value recorded on October 1st (12.286) g. The results indicated that the interaction between Chilling N/P ratio showed significant difference between means value with all chilling periods and 100/100 N/P ratios where highest value obtained from 10 days 100/100 N/P (12.155) g and 20 days 100/100 N/P (11.923) g respectively in both years.

The triple interaction showed a significant difference when N/P was sprayed on chilled transplants for 10 days on Sep. 15th and gave (13.68), and with a chilled one for 20 days sprayed with 100/100 N/P on October 1st (13.533) g for the two seasons gradually. Lowest values were (8.465) g between 15th October, 10 days and no N/P and (7.587) g between 15th October, 20 days and no N/P respectively in both years.

Table 3: Effect of planting dates, chilling, N/P ratio and their interactions on root dry matter (%) of strawberry cv. Robygem in 2022-2023

Time of Planting	Chilling of plants (4 ±1⁰C)	N/P ratio				Time*Cooling		Means of Time	
		2022		2023					
		0	100/100	0	100/100	2022	2023	2022	2023
15th Sep.	0	10.98 bcd	13.233 ab	9.928c-f	11.36 bc	12.11 a	10.65abc	11.72 a	10.76 a
	10	10.79 bcd	13.68 a	11.05bcd	11.46 bc	12.24 a	11.25 ab		
	20	10.59 bcd	11.05 a-d	9.15 efg	11.62 bc	10.82 ab	10.39 bc		
1st Oct.	0	9.335 cd	11.64 abc	8.43 fg	11.19 bc	10.49 ab	9.809 cd	10.66 b	10.65 a
	10	9.947 cd	11.59 abc	8.76 fg	12.14 ab	10.77 ab	10.45 bc		
	20	9.683 cd	11.78 abc	9.875 c-f	13.53 a	10.74 ab	11.7 a		
15th Oct.	0	9.767 cd	10.58 bcd	9.26 d-g	12.39 ab	10.17 b	10.83abc	10.14 b	9.957 b
	10	8.465 d	11.19a-d	8.16 fg	11.73 bc	9.83 b	9.944 cd		

	20	9.41 cd	11.44 abc	7.587 g	10.61 b-e	10.43 ab	9.1 d		
Time* N/P ratio	15thSep.	10.79 bc	12.65 a	10.04 b	11.48 a	Means of Cooling			
	1st Oct.	9.655 cd	11.67 ab	9.02 c	12.29 a				
	15thOct.	9.214 d	11.07 b	8.34 c	11.58 a	2022	2023		
Chilling* N/P ratio	0	10.03 b	11.82 a	9.291 b	11.65 a	10.92 a	10.43 a		
	10	9.734 b	12.16 a	9.323 b	11.78 a	10.95a	10.55 a		
	20	9.894 b	11.43 a	8.870 b	11.92 a	10.66 a	10.39 a		
Means of N/P		9.885 b	11.79 a	9.133 b	11.78 a				

Means of each factor and their interactions followed by different letters are significant by different from each other according to Duncan's multiple range test at 5%.

4. Vegetative dry matter (%)

Data in (Table 4) explain planting date effect on vegetative dry matter (V. dry matter) gram of strawberry. Planting on 15th September had significant differences and recorded highest value (193.231 and 16.224) g in 2022 and 2023. Lowest value obtained on 1st October which was (17.554) g in the first growing season. Lowest value was (17.554) g on 1st October and (15.009) obtained on 15th October.

Mean effect of chilling showed significant effect between means value in 10 days of chilling in both growing season (19.666 and 16.62) g. Concerning the effect of N/P ratio it was appeared that there were significant effect recorded in plant with 100/100 in both years which recorded maximum value (19.763 and 16.913) g respectively compared to not N/P ratio treatment.

The bilateral interaction between (Time and chilling) the effects were significant, in the first and second years. The highest means of V. dry weight were obtained from the interaction of first time with 10 days chilling in both seasons which recorded the highest values (21.051 and 18.091) g respectively.

Time of planting and N/P interaction had significant effects on the V. dry matter in 2022 and 2023. Highest values were (20.222) g between 15th October and 100/100 in 2022 and (17.43) g between 15th Sep. and 100/100 in 2023.

The interaction between (Chilling*N/P ratio) the effects were significant, in the first and second years. The highest means of V. dry weight were obtained from the interaction of 10 chilling days with 100/100 recording (20.205 and 17.409) g respectively in both years compared to other mean values.

The interaction among the three experimental factors (Time *chilling and N/P ratio) significantly affected on strawberry V. dry matter. The interaction between the 15th September, second chilling of the transplants (4 ±1^{0}C) and the 100/100 N/P ratio produced the maximum V. dry weight, which was the only significant among all mean values for the first growing season and yielded (21.728) g. In contrast, the significant value among three factors that produced (19.255) g. In comparison with the other interactions in the second season was on October 1st, 20 days of chilling and 100/100 N/P. Lowest values were (13.775) g on 1st October and controls in 2022 and (11.328) g on 15th September 20 days chilling and control.

Table 4: Effect of planting dates, chilling, N/P ratio and their interactions on leaf area (cm^2 /plant) of strawberry cv. Robygem in 2022-2023.

Time of Planting	Chilling of plants (4 ± 1^{0}C)	N/P ratio				Time*Cooling		Means of Time	
		2022		2023		2022	2023	2022	2023
		0	100/100	0	100/100				

15th Sep.	0	93.52 ab	114.34 ab	89.55 def	115.5 ab	103.9 ab	102.5 bc	106.4 a	102.9 a
	10	113.5 ab	115.87 a	112.6 abc	120.6 a	114.7 a	116.6 a		
	20	93.69 ab	107.5 ab	84.98 def	94.5 c-f	100.6 ab	89.7 cde		
1st Oct.	0	90.14 ab	110.8 ab	84.59 def	102.5 a-d	100.4 ab	93.52 b-e	102.8 ab	95.72 b
	10	102.62 ab	120.5 a	84.92 def	95.01 c-f	111.7 ab	89.99 cde		
	20	83.76 b	108.9 ab	85.71 def	121.6 a	96.35 ab	103.7 b		
15th Oct.	0	97.18 ab	93.91 ab	78.9 ef	97.495 b-e	95.55 ab	88.19 de	94.51 B	88.38 c
	10	84.3 b	107.7 ab	86.91 def	103.633 a-d	95.98 ab	95.27 bcd		
	20	83.39b	100.6 ab	75.96 f	87.195 def	91.99 b	81.58 e		
Time* N/P ratio	15thSep.	100.2 ab	112.6 a	95.69 b	110.2 a	Means of Cooling			
	1st Oct.	92.17 b	113.4 a	85.08 c	106.4 a	2022	2023		
	15thOct.	88.29 b	100.7 ab	80.59 c	96.12 b				
Chilling* N/P ratio	0	93.62 bc	106.4 ab	84.35 c	105.1 ab	99.98 ab	94.74 ab		
	10	100.1 abc	114.7 a	94.8 b	106.4 a	107.4 a	100.61 a		
	20	86.94 c	105.7 ab	82.22 c	101.1 ab	96.31b	91.65 b		
Means of N/P		93.56 b	108.9 a	87.12 b	104.2 a				

Means of each factor and their interactions followed by different letters are significant by different from each other according to Duncan's multiple range test at 5%.

5. Leaf area (cm² /plant)

Data in (Table 5) displays the effects on strawberry leaf area (cm² /plant) for two years. About planting dates effect, Leaf area was significantly varied by the planting dates, planting on September 15th in two seasons had significant differences record between means values compared to the other dates which recorded highest (106.401 and 102.94 cm²) respectively in both years. Value Mean effect of chilling duration showed significant effects for two seasons with 10 chilling period which recorded (107.4 and 100.61 cm²) respectively. Concerning the effect of N/P ratio it was appeared that there were significant effect recorded in plant with 100/100 which recorded maximum value in both season compared to 0 N/P ratios (108.908 and 104.225 cm²) respectively.

Concerning to the bilateral interaction between (Time and cooling) the effects were significant in the first and second years from the interaction between Sep. 15th and 10 chilling periods which recorded the highest values (114.66 and 116.586 cm²) respectively. The interaction between the factors (Time*N/P ratio) had a significant effect with 100/100 on October 1st (113.423 cm²) in 2022 compared to other interactions means values, And 100/100 ratio on September 15th (110.199 cm²) in 2023. The results indicated that the interaction between Chilling *N/P ratio showed significant difference, the highest values obtained with 10 chilling period and 100/100 ratio (114.68 and 106.43 cm²) respectively in both years.

Table 5: Effect of planting dates, chilling, N/P ratio and their interactions on leaf area (cm² /plant) of strawberry cv. Robygem in 2022-2023.

Time of Planting	Chilling of plants (4 ± 1⁰C)	N/P ratio				Time*Cooling		Means of Time	
		2022		2023		2022	2023	2022	2023
		0	100/100	0	100/100				
15th Sep.	0	93.52 ab	114.34 ab	89.55 def	115.5 ab	103.9 ab	102.5 bc	106.4 a	102.9 a
	10	113.5 ab	115.87 a	112.6 abc	120.6 a	114.7 a	116.6 a		
	20	93.69 ab	107.5 ab	84.98 def	94.5 c-f	100.6 ab	89.7 cde		
1st Oct.	0	90.14 ab	110.8 ab	84.59 def	102.5 a-d	100.4 ab	93.52 b-e	102.8 ab	95.72 b
	10	102.62 ab	120.5 a	84.92 def	95.01 c-f	111.7 ab	89.99 cde		
	20	83.76 b	108.9 ab	85.71 def	121.6 a	96.35 ab	103.7 b		
15th Oct.	0	97.18 ab	93.91 ab	78.9 ef	97.495 b-e	95.55 ab	88.19 de	94.51 b	88.38

	10	**84.3 b**	**107.7 ab**	**86.91 def**	**103.633 a-d**	**95.98 ab**	**95.27 bcd**		**c**
	20	**83.39b**	**100.6 ab**	**75.96 f**	**87.195 def**	**91.99 b**	**81.58 e**		
Time* N/P ratio	**15thSep.**	**100.2 ab**	**112.6 a**	**95.69 b**	**110.2 a**	**Means of Cooling**			
	1st Oct.	**92.17 b**	**113.4 a**	**85.08 c**	**106.4 a**	**2022**	**2023**		
	15thOct.	**88.29 b**	**100.7 ab**	**80.59 c**	**96.12 b**				
Chilling* N/P ratio	**0**	**93.62 bc**	**106.4 ab**	**84.35 c**	**105.1 ab**	**99.98 ab**	**94.74 ab**		
	10	**100.1 abc**	**114.7 a**	**94.8 b**	**106.4 a**	**107.4 a**	**100.61 a**		
	20	**86.94 c**	**105.7 ab**	**82.22 c**	**101.1 ab**	**96.31b**	**91.65 b**		
Means of N/P		**93.56 b**	**108.9 a**	**87.12 b**	**104.2 a**				

Means of each factor and their interactions followed by different letters are significant by different from each other according to Duncan's multiple range test at 5%.

The interaction among the three experimental factors (Time, Cooling and N/P ratio) significantly affected on strawberry leaf area. The maximum leaf area was obtained as a result of interaction among 1st October and 10 Chilling of Transplants (4 ± 1^0C) with the 100/100 N/P ratio, which gave (120.52 cm^2) in 2022. In 2023 highest value was (121.59 cm^2) between 1st October 20 days chilling and 100/100 compared with the others interactions. The lowest values were recorded among combination

the third time of planting *Chilling of transplants (4 ±1 ^{0}C) 20 and with no N/P ratio which gave lowest value and (83.385 and 75.957 cm^2) in both years of growing.

This finding shows maximum leaf area, crown diameter, R. dry matter and V. dry matter from early planting than that of late planting. Plants of mid–September planting had better growth than other plantings, perhaps because of availability of better climatic conditions which were favorable for growth and development of plants (Voth and Bringhurst, 1970). Chilling process increase vegetative parameters like V. dry matter and leaf area. Chilling periods for 10 days was the most significant effective in most traits. Results may be interpreted to mean exposing plants to effective low temperatures for several days positively affects many physiological phenomena and functions of plants, especially stimulating vegetative and root growth of these plants (Devlin, 1975; Singh *et al.*, 2007; Sharma and Yamdagni, 2000; Hokanson, 2004). N/P spraying increased almost all traits. The results confirmed that urea spraying resulted in a significant increase in all studied vegetative and root growth compared to the control treatment for both years, These results are in line with Santos (2010) and Mohamed (2021).The reason for this may be due to the increase in leaf chlorophyll content when foliar spraying with urea which may result in an increase in nutrients synthesized in the leaves by photosynthesis and used by the plant in its various vegetative and root growths (Havlin *et al.*, 2005).

CONCLUSION & RECOMMENDATIONS

The results indicated that optimal strawberry growth is influenced by several factors, September 15th to October 1st considered optimal planting date by carefully selecting planting dates, Ideal N/P Ratio: 100/100 can optimize strawberry growth and achieve maximum crown diameter and a 10-day chilling period is considered beneficial. These findings provide a framework for maximizing strawberry growth by carefully selecting planting dates, maintaining the correct N/P ratio, and utilizing a strategic chilling period.

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Novelty statement: The study provides essential information on strawberry response towards different factors under hydroponic conditions.

Contributions of authors

H.O. A: Constructed the idea and hypothesis for research; planned the methodology, analyzed the data, and wrote the manuscript.

SH.H. S: Constructed the idea and hypothesis for research.

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