Original Article

Effect Of Different Environments And GA_3 On Growth And Runners Production Of Strawberry (Frageria Ananasa)

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Abstract

Strawberry (Frageria ananasa) is the fruit of temperate climate but some cultivars are adaptable to sub-tropical climate as well. In Pakistan, strawberry runners are only produced in Swat Mingora, Khyber Pakhtunkhwa. This research was aimed to produce runners in Punjab environments. Therefore this research was carried out at Pir Mehar Ali Shah Arid Agriculture University Rawalpindi, during the years 2017-18. Strawberry cultivar "Chandler" were treated with different concentrations (control, 150 ppm, 300 ppm and 450 ppm) of gibberellic acid in four different environments (open field, plastic tunnel, glass house and lath house) to investigate their effect on vegetative growth and runners production. Data was recorded for plant height, crown diameter, petiole length, count of leaves, count of trusses, count of runners, leaf area, weight of fresh leaves, weight of dry leaves and canopy size. Results unveiled that strawberries cultivated in a lath with 450 ppm GA_3 application gave exceptional results for all the observed parameters except crown diameter and canopy spread, which were superior in open field crop and treated with 450 ppm GA_3 solution. Hence it can be concluded that strawberries cultivated in a lath house with 450 ppm GA_3 application produces excellent quality plants and capable to produce runners for the next season.

Keywords: Strawberry, Gibberellic acid (GA_3), Environmental conditions, vegetative characters, runners production

INTRODUCTION

Strawberry (Frageria ananasa) is the member of the family Rosaceae which is cultivated in the temperate and subtropical area of world (Vishal et al., 2017). The world production of strawberry was documented as 5.84 million metric tons and the United States of America ranked 1st with 1148510 metric tons of production (FAO, 2010). National Agriculture Research Center (NARC) Islamabad was the first institute who began strawberry cultivation in 1986 in Pakistan (GOP, 2009). However, the average yield of strawberry per hectare of Pakistan is very low when compared with the major strawberry cultivating countries such as United State of America and Turkey because of poor cultural practices, unavailability

of market and infrastructure for transportation, lack of cold storage which may decreased the economic importance of strawberry production amongst the growers (Mabood, 1994). Strawberry is the largest yielding crop cultivated on 506,000 acres of land in 71 nations around the globe. The average yield of strawberry in the world is approximately 14000 lbs per acre (Husaini, & Abdin, 2008).

Strawberry is characterized by a herbaceous, short day plants cultivated for its lovely fruit, aroma, taste, fresh use, freezing and processing (Uddin et al., 2012). The strawberry fruit in generally valued for its bright red colour, juicy surface, aroma and are consumed in big amounts in making juices, desserts, pies and milk shake. The aroma is scientifically used in industrialized food products. Strawberry compared to other horticultural berry fruits, it comprises a greater amount of fiber, phenolics, vitamins, and flavonoid (Kumra et al., 2018). Nutritionally, strawberry is a low calorie carbohydrate fruit but wealthy source of vitamin C (40-130 mg/100g of eatable portion), vitamin A (65 IU/100g of eatable portion), fiber and also has high pectin percentage (0.50%) available in the form of calcium pectate. Water is a significant component of strawberry fruit it contain (85%) of water.

In the last decades the farming of strawberry was limited to temperate regions of world rendering it to price hiking. In the climate of Pakistan the following varieties of strawberry are grown namely Pajaro, Corona, Douglus, Toru, Tufts, and Chandler. The two main varieties Chandler and Toru are commercially grown in Islamabad and other area while others varieties pajaro and douglus are cultivated for research purpose (Khushk & Memon, 2009). Chandler is an excellent strawberries cultivar for plastic culture and which also performs excellent in open environmental conditions. Strawberry grown in the plastic tunnel began to bear fruit 30 days before those produced fruits in the open field (Jett, 2006). High tunnels with various designs estimate less than $ 0.50/ square feet which are low-cost to build in comparison with green houses (Black et al., 2008). Strawberry cultivation in high tunnels provides benefit in economical production of strawberry for a long season (Rawley et al., 2010). Phillips & Reid (2008) recommended cultivation of strawberries in low tunnel due to best protection from climatic factor as compared to field and high tunnels.

For optimum growth and developments strawberry plants require full sun, moist, slightly acidic and well-drained soil in the pH range 5-6 and the best timing for planting of strawberry is early spring. Strawberry has chilling requirement like other temperate fruits to complete its life cycle properly. Chilling is necessary to break the strawberry dormancy (Lieten et al., 1995) in light of chilling plant obtain and quicken blossoming capacity (Sung & Amasino, 2004). In the event that strawberry plants are developed under high temperature and long photoperiod, the petiole length of dormant plants does not extend when contrasted with appropriately chilled plants (Lee, Takahashi, & Sugiyama, 1970). Day neutral cultivars of strawberry when given vernalization produces more and bigger fruits than un-chilled plants (Bringhurst & Voth, 1987).

Gibberellin is a group of natural plant hormones, which got from the fungus gibberella and numerous higher plants. Gibberellin are produced industrially in crystalline structure as acids or potassium salts. They play various regulatory function such as stimulation of development enhancing cell division, cell elongation, beginning of blossoming, sex assurance, fruit setting, fruit growth, ripening of certain fruits, senescence of leaves, and breaking dormancy period of seeds and buds. Gibberellins are said to be most effective and essential set of plant hormone (Malik & Bashir, 1994). The sprayed gibberellin is absorbed by plants and moved to auxiliary buds. The vegetative attributes, like number of leaves, area of leaves, crown weight, crown diameter, number of runner and plantlets number (daughter plants) are affected by growth regulators (Porlingis & Boynton, 1961. Plant growth regulators are commercially implemented in order to increase crop quality and productivity.

Presently, strawberry runners are being produced in the province Khyber Pakhtunkhwa district Swat Mingora for distribution in Pakistan. Strawberry runner production is not possible in the Punjab environments therefore, this research was conducted to investigate the possibilities of runner production under different environmental conditions.

The present research on growth and yield response of strawberry was performed with the following objective:

- To examine the effect of GA_3 on strawberry growth and runners production.

- To assess the effect of environmental conditions on growth and runners production of strawberry.

Materials and methods

The field experiment was conducted under different environments at Horticulture Research field of (PMAS-AAUR) Pir Mehar Ali Shah Arid Agriculture University Rawalpindi, during the years 2017-18. The research work was conceived to examine the impacts of different environments and gibberellic acid concentrations on vegetative characteristics and runners production. Strawberry runners of cultivar "Chandler" were obtained from Mingora Swat valley. The clay pots of capacity 3 liters have been used for planting of runners. The composition of media containing sand, silt and Farm Yard Manure (FYM) at ratio of 1:1:1. The field experiment was designed according to Randomized Complete Block Design (RCBD) and three replication were made to check the effect of foliar application of gibberellic acid in four different environments on growth, productivity and quality parameters of strawberry, in each replication 7 plants were placed and the treatments used are listed in Table 1. Data was recorded for plant height, crown diameter, petiole length, count of leaves, count of trusses, count of runners, leaf area, weight of fresh leaves, weight of dry leaves and canopy size.

Statistical analysis

The collected data were analyzed by using STATISTIX 8.1 analysis of variance technique was implemented and the least significant difference LSD test at 5 percent probability level to checked the considerable variation among the treatments and means results were compared (Steel et al., 1997).

Table 1. Treatment combinations of GA_3 and Environments

Treatments	Environments	GA_3 Concentrations
T_1	Open Field (E_1)	Control (Distil water)
T_2	Open Field (E_1)	150 ppm
T_3	Open Field (E_1)	300 ppm
T_4	Open Field (E_1)	450 ppm
T_5	Plastic Tunnel (E_2)	Control (Distil water)
T_6	Plastic Tunnel (E_2)	150 ppm
T_7	Plastic Tunnel (E_2)	300 ppm
T_8	Plastic Tunnel (E_2)	450 ppm
T_9	Glass House (E_3)	Control (Distil water)
T_{10}	Glass House (E_3)	150 ppm
T_{11}	Glass House (E_3)	300 ppm
T_{12}	Glass House (E_3)	450 ppm
T_{13}	Lath House (E_4)	Control (Distil water)
T_{14}	Lath House (E_4)	150 ppm
T_{15}	Lath House (E_4)	300 ppm
T_{16}	Lath House (E_4)	450 ppm

Results and Discussion

The results regarding to the role of environmental conditions and plant growth regulator effects on both vegetative parameters and reproductive growth and quality attributes of strawberry plant are presented and discussed as follows:

Plant Height (cm)

The mean results related to plant height are presented in Table 2. The mean data exposed that there was a considerable effect of gibberellic acid on plants height of strawberry plant while environments effect was significant on plant height. The interactive effect of gibberellic acid and environments on plant height of strawberry plant was also significant.

The results showed that the highest plant height (25.62 cm) was noted in strawberry plants, sprayed with 450 ppm of GA_3 while lowest plant height (18.36 cm) perceived in plants, sprayed with distil water. The interaction between gibberellic acid and environments on strawberry plant height was also significant. The highest plant height (25.96 cm) was perceived in plants, sprayed with GA_3 450 ppm which were kept in lath house (E_4), However, the lowest plant height (17.03 cm) recorded in plants, received distil water in open field (E_1).

The findings of this research have shown that maximum plant height was increased by gibberellic acid concentration of 450 ppm. Guttridge & Thompson (1964) reported that the plant height was stimulated by long day induced into short days as temperature rises. Qureshi et al. (2013) in relation to gibberellic acid treatments during winter favored in spring. Data of the current study are consistent with Ouzounidou et al., 2010; Kasim et al., 2007, they recommended rise in height of plant in artichoke and chilli plant.

Crown Diameter (cm)

The data on the crown diameter presented in (Table 3). The results exposed that there was a considerable effect of gibberellic acid on crown diameter of strawberry crop while environments effect was also significant on crown diameter. The interactive effect of gibberellin and environments on crown diameter of strawberry was also significant.

The results clearly indicate that the highest crown diameter (3.46 cm) was noted in strawberry plants, treated with 450 ppm gibberellic acid while minimum crown diameter (1.28 cm) observed in plants, sprayed with distal water. The data regarding combination of environments and GA_3 the highest crown diameter (3.66 cm) was noted in plants, sprayed with 450 ppm gibberellic acid which were kept in open field (E_1), However, the minimum crown diameter (1.18 cm) recorded in plants, received distal water which were kept in glass house (E_3).

The results associated to crown diameter indicated that GA_3 application @ 450 ppm considerably increased crown diameter whereas other treatments of gibberellic acid, environments and the combinations influenced the crown diameter of strawberries plants. Gibberellic acid application was essentially reflected as increase in crown height and crown spread. The present study is related with the investigation of Hytonen et al. (2009) who recommended that GA_3 considerably influence the vegetative parameters specifically leaves number, canopy spread, runners number and number of laterals branches. GA_3 significantly increased total carbohydrates contents crowns and roots of strawberry plant the research was presented by Ragab, 1996.

Petiole Length (cm)

The effects of growth regulator and environments on petiole length of strawberry leaves are shown in (Table 4). Means data revealed that there was a significant impact of GA_3 and environments on petiole length of strawberry plants. The interaction between gibberellic acid and environments on petiole length was also significant.

The results showed that the maximum petiole length (25.36 cm) was noted in strawberry plants, sprayed with gibberellic acid 450 ppm however, minimum petiole length (14.05 cm) was observed in plants, sprayed with distil water. The interactive impact of gibberellic acid and environments on petiole

length of strawberry was also significant. The maximum petiole length (25.89 cm) was recorded in plants, sprayed with 450 ppm gibberellic acid which were kept in lath house (E_4), however, the minimum petiole length (13.76 cm) recorded in plants, sprayed with distil water which were kept in glass house (E_3).

Gibberellic acid had a crucial role in several important biochemical and morphogenetic reactions in plants the petiole length was highly influenced by the application of gibberellin. From current results it is shown that petiole length of strawberry plant increased by application of gibberellic acid when applied alone or with combination with other, due to the acceleration of cell division at leaves position (Nishizawa, 1990). Gibberellin had also boosted the division of cell, which may be potential reason for the high petiole length contribution. Our conclusions agreed with the outcome of (Dwivedi et al., 1999; Paroussi et al., 2002).

Count of Leaves

The mean data dependable on count of leaves are presented in (Table 5). The means data disclosed that there was a considerable effect of GA_3 on count of leaves of strawberry while environments effect was also significant. The interactive effect of GA_3 and environments on count of leaves of strawberry was significant.

The results revealed that the highest leaf numbers (13.67) were recorded in strawberry plants, sprayed with gibberellic acid 450 ppm however, lowest leaves number (7.10) observed in plants, sprayed with distal water. The interactive effect of gibberellic acid and environments on count of leaves of strawberry was significant. The highest leaves number (14.18) were observed in plants, sprayed with gibberellic acid at 450 ppm which were kept in lath house (E_4), however, the lowest leaves number (6.76) recorded in plants sprayed with distal water which were kept in open field (E_1).

Gibberellic acid greatly increased vegetative growth. The strawberry variety 'Chandler' shown a very significant response to gibberellic acid treatments on vegetative growth (Sharma & Singh, 2009a). The finding of our research are related to Waithaka et al., (1978) they reported that leaves numbers had been increased with gibberellic acid concentration increasing. February treatments of GA_3 was more effective from November treatments its improved the vegetative parameters due to increased temperature which are ideal for vegetative growth following GA_3 treatments in February (Martinez et al., 1994). The present research study showed that environmental conditions not only increased the number of leaves during vegetative developments but also sustained it through its life span whereas it was reported that the GA_3 treatments during the process of data collection the leaves number were higher at vegetative growth phase but as the reproductive phase and runners production started the count of leaves decreasing due to all the stored energy moving to runners.

Count of Trusses

The results associated with number of trusses of strawberry plant are presented in (Table 6). The means data showed that there was a significant impact of gibberellic acid on number of trusses of strawberry and environments effect was also significant on number of trusses. The interactive effect of GA_3 and environments on number of trusses of strawberry was also significant.

The data related to number of trusses per plant is shown in (Table 6) which disclosed that highest (2.79) trusses were produced by treatments of GA_3 at 450 ppm concentration, whereas the lowest (1.42) trusses were produce by distil water while the environmental effects on number of trusses were produce maximum (2.54) trusses were recorded in lath house (E_4) and the minimum (1.97) trusses were recorded in the open field (E_1), The interactive effect of gibberellic acid and environments were the highest (3.12) trusses were found by spraying gibberellic acid at 450 ppm which were kept in glass house (E_3) while the minimum (1.29) number of trusses were recorded in plastic tunnel (E_2) treated with distil water.

As prior literature on gibberellic acid indicated that it also influenced production of flowers in all horticultural crops including strawberries, likewise it increased the trusses numbers per plant and this is because of plant growth regulator (PGR) which stimulates foreign production. Our study is consistent with the outcome of Gutridge & Thompson (1964) they reported that the trusses numbers in strawberry

increased by GA_3. In the production of flowering and inflorescence gibberellic acid had played crucial role. (Takahashi et al., 1991).

Count of Runners

The analyzed data regarding the count of runners presented in (Table 7) which showed that highest count of runners were produced by GA_3 either alone or in combine with environments lath house (E_4). Gibberellic acid 450 ppm contributed to maximum (19.78) runners per plant while distil water have least number (9.23) of runners per plant. The interaction between gibberellic acid 450 ppm and environments lath house (E_4) produced the higher (21.44) count of runners per plant while the least (8.15) number of runners were recorded in glass house (E_3) treated with distil water.

Gibberellin had played a function in axillary bud differentiation which may be the cause for the runner production described by (Black, 2004). Growth promoters are the reason which affected runners plants yield as well as its qualities reported by (Wang, 1992). The count of runners in GA_3 sprayed plants increased considerably. In particular, GA_3 encourages cell elongation and division under the apical meristem by (Arteca, 1995). Choma & Himelrick (1983) reported a similar view, showing the increased in the runner numbers after gibberellin was applied. Gibberellic acid greatly improved the runner numbers of plants and produce a positive result for runner production. Findings of the present research agreed with (Hytonen et al., 2008; Kumar et al., 2008). Anna & Ialichino, (2002) reported that cultural practices and latitude of the area of production are other factors. Hytonen et al. (2009) investigated that the short day cultivar of strawberry plants were sprayed by GA_3 before flowering, in long days they began to produce runners.

Leaf Area (cm^2)

The results related to leaf area are presented in (Table 8) that the significant observation was noted between combined treatments of growth regulator GA_3 and environments. Results recording growth regulator GA_3 and environmental conditions showed the highest leaf area (138.73 cm^2) in lath house which were treated with 450 ppm gibberellic acid. While the lowest leaf area (73.15 cm^2) was noted in treatment of distil water in glass house (E_3). The data regarding environments showed the highest leaf area (119.10 cm^2) are observed in open field (E_1) while the lowest leaf area (111.13 cm^2) in glass house (E_3).

Sharma & Singh, (2009b) showed similar results with our present research, they indicated that GA_3 growth promoter had substantial beneficial effect on growth of the leaf area of strawberry plants. The growth regulator may effects partitioning assimilation, resulting in reduced leaf growth in low assimilation to shoots, and block biosynthesis of gibberellic acid and reducing leaf area. GA_3 when applied to various plants they improved the vegetative parameters such as leaves number and leaf area. In our present research, the highest values of leaf area were produced by GA_3 application alone or in combine are comparable to the outcomes of Paroussi et al., 2002.

Weight of Fresh Leaves (g)

The means results in (Table 9) showed that the highest weight of fresh leaves (37.74 g) were observed in plants, received 450 ppm gibberellic acid in lath house (E_4), while, the minimum (14.72 gm) weight of fresh leaves was recorded in plants, grown in plastic tunnel (E_2) which were sprayed with distil water.

The okra plants treated with GA_3 showed an increased in fresh and dries weights, length of roots and shoots and leaf area related with plant treated with NaCl only (Jasmine & Marina, 2012). Gibberellic acid had influenced the vegetative growth particularly leaves, GA_3 had generated more leaves number per plant than control when treated alone or in combine with other treatments, because GA_3 enhanced health of a strawberry plants earlier investigated by (Sharma & Singh, 2009b; Ouzounido et al., 2010). The outcome of present study were parallel to the outcome of Gutierrez et al., (1998) who directed that in soybean plants the increase in shoots and roots growth are responsed to GA_3 application.

Weight of Dry Leaves (g)

Results regarding the weight of dry leaves is given in (Table 10). The highest significant values (0.79 g) were found in the environmental condition of lath house (E_4) which was treated with 450 ppm gibberellic acid and the lowest significant values (0.32 g) were recorded in environmental condition of plastic tunnel (E_2) which was sprayed with distil water. The results regarding gibberellic acid that the maximum values (0.71 g) were recorded at concentration 450 ppm GA_3 and the minimum values (0.35 g) were noted in plants treated with distil water.

The outcome of our research are inline with the results of (Ouzounido et al., 2010; Sharma and Singh, 2009b) who indicated that GA_3 considerably enhanced dry weight of shoot, accumulation of dry matter and leaves photosynthetic activities. The results of the present research are similar with Alvim (1960) who proposed that treatments of gibberellic acid increased in weight of fresh and dry leave of strawberry.

Canopy Spread (cm)

The means results regarding canopy spread are shown in (Table 11). The maximum canopy spread (28.29 cm) was noted in open field condition (E_1) which were sprayed with gibberellic acid at concentration 450 ppm while lowest canopy spread (20.60 cm) was observed in glass house (E_3) which was treated with distal water. A significant variation amongst canopy spread observed regarding GA_3. The highest canopy spread (27.58 cm) was perceived in plants sprayed with 450 ppm GA_3; however the least canopy spread (21.53 cm) was recorded with distal water. The maximum canopy spread regarding environments (25.56 cm) was observed in open field (E_1) while the lowest (24.34 cm) was recorded in glass house (E_3).

The current research is related to the research of Martinez et al., 1994, who recommended that after spraying of gibberellic acid the vegetative growth increased such as leaf number, diameter of crown, leaf area and canopy spread. As previous results indicated by (Singh & Kaul, 1970; Martinez et al., 1994) who proposed gibberellic acid application to assist increasing petiole length, leaf area, crown spread or height, canopy size and number of leaves. Gibberellic acid greatly improved the distinct parameters of vegetative growth in various fruits as well as in strawberry.

Table 2. Effect of gibberellic acid and environment on plant height (cm) of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	17.03 f	21.29 c	21.61 c	25.41 a	**21.33 b**
Plastic tunnel (E_2)	18.69 e	21.50 c	22.51 b	25.51 a	**22.05 a**
Glass house (E_3)	18.76 e	21.12 c	22.69 b	25.59 a	**22.04 a**
Lath house (E_4)	18.95 e	20.13 d	22.72 b	25.96 a	**21.94 a**
Means	**18.36 d**	**21.01 c**	**22.38 b**	**25.62 a**	

Table 3. Effect of gibberellic acid and environments on crown diameter of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	1.29 ef	1.65 de	2.19 bc	3.66 a	**2.20 ab**
Plastic tunnel (E_2)	1.29 ef	1.48 de	2.58 b	3.62 a	**2.24 a**
Glass house (E_3)	1.18 f	1.91 cd	2.52 b	3.23 a	**2.21 a**
Lath house (E_4)	1.36 e	1.50 de	1.90 cd	3.33 a	**2.02 b**
Means	**1.28 d**	**1.63 c**	**2.30 d**	**3.46 a**	

Table 0. Effect of gibberellic acid and environments on petiole length of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	14.22 gh	15.36 def	17.58 bc	25.37 a	**18.13 ab**
Plastic tunnel (E_2)	13.87 h	15.65 efg	16.52 cde	25.29 a	**17.63 b**
Glass house (E_3)	13.76 h	14.67 fgh	16.92 cd	24.88 a	**17.58 b**
Lath house (E_4)	14.05 h	14.66 fgh	18.37 b	25.89 a	**18.49 a**
Means	**14.05 d**	**15.08 c**	**17.35 b**	**25.36 a**	

Table 5. Effect of gibberellic acid and environment on count of leaves

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	6.76 g	8.55 e	9.51 d	13.65 b	**9.62 b**
Plastic tunnel (E_2)	7.16 fg	8.21 e	10.18 c	13.51 b	**9.99 a**
Glass house (E_3)	7.32 f	8.24 e	10.54 c	13.32 b	**9.85 ab**
Lath house (E_4)	7.17 fg	8.62 e	9.18 d	14.18 a	**9.79 ab**
Means	**7.10 d**	**8.47 c**	**10.01 b**	**13.67 a**	

Table 6. Effect of gibberellic acid and environments on number of trusses

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E1)	1.57 fgh	2.14 de	2.11 def	2.12 def	**1.97 b**
Plastic tunnel (E2)	1.29 h	2.14 de	2.09 efg	2.90 ab	**2.10 b**
Glass house (E3)	1.32 h	2.22 abc	2.61 cd	3.12 a	**2.31 a**
Lath house (E4)	1.52 gh	2.62 cd	2.95 bc	3.07 a	**2.54 a**
Means	**1.42 c**	**2.28 b**	**2.44 b**	**2.79 a**	

Table 7. Effect of GA_3 and environments on count of runner of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	83.22 gh	120.8 def	128.6 abcd	137.18 ab	**119.10 a**
Plastic tunnel (E_2)	74.31 h	112.69 f	125.54 cde	135.51 abc	**117.47 ab**
Glass house (E_3)	73.15 h	114.66 ef	126.47 bcd	135.25 abc	**111.13 b**
Lath house (E_4)	86.15 g	121.7 def	129.7 abcd	138.73 a	**112.38 b**
Means	**79.21 d**	**117.48 c**	**127.61 b**	**136.67 a**	

Table 8. Effect of gibberellic acid and environments on leaf area of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	83.22 gh	120.8 def	128.6 abcd	137.18 ab	**119.10 a**

Plastic tunnel (E_2)	74.31 h	112.69 f	125.54 cde	135.51 abc	**117.47 ab**
Glass house (E_3)	73.15 h	114.66 ef	126.47 bcd	135.25 abc	**111.13 b**
Lath house (E_4)	86.15 g	121.7 def	129.7 abcd	138.73 a	**112.38 b**
Means	**79.21 d**	**117.48 c**	**127.61 b**	**136.67 a**	

Table 9. Effect of gibberellic acid and environments on weight of fresh leaves of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	15.72 h	21.86 fg	26.63 c	37.34 ab	**25.39 b**
Plastic tunnel (E_2)	14.72 hi	21.42 g	24.71 de	36.801 ab	**24.39 c**
Glass house (E_3)	15.71 hi	21.32 g	25.66 cd	36.21 b	**24.75 bc**
Lath house (E_4)	16.65 h	23.25 ef	27.14 c	37.74 a	**26.20 a**
Means	**15.71 d**	**21.96 c**	**26.04 b**	**37.02 a**	

Table 10. Effect of gibberellic acid and environments on weight of dry leaves of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	0.45 d	0.51 cd	0.58 bc	0.77 a	**0.58 a**
Plastic tunnel (E_2)	0.32 e	0.51 cd	0.58 bc	0.64 b	**0.52 b**
Glass house (E_3)	0.32 e	0.52 cd	0.52 cd	0.64 b	**0.51 b**
Lath house (E_4)	0.33 e	0.49 cd	0.56 bcd	0.79 a	**0.54 ab**
Means	**0.35 d**	**0.50 c**	**0.55 b**	**0.71 a**	

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Table 11. Effect of gibberellic acid and environments on canopy spread of strawberry

	Gibberellic acid (ppm)				
Environments	0	150	300	450	**Means**
Open field (E_1)	22.39 g	25.40 de	26.18 cd	28.29 a	**25.56 a**
Plastic tunnel (E_2)	20.74 h	24.10 f	26.28 cd	27.14 abc	**24.57 b**
Glass house (E_3)	20.60 h	23.84 f	25.94 cde	26.99 bc	**24.34 b**
Lath house (E_4)	22.38 g	24.81 ef	25.95 cde	27.92 ab	**25.27 a**
Means	**21.53 d**	**24.54 c**	**26.09 b**	**27.58 a**	

Conclusion and Recommendations

Findings of this research concluded that all the observed parameters were significantly affected by application of different concentrations of Gibberellic acid and various environmental conditions. Results revealed that strawberries grown in a lath and then treated with 450 ppm GA3 produced superior results regarding plant height, petiole length, count of leaves, count of trusses, count of runners, leaf area, weight of fresh leaves and weight of dry leaves. Only two characteristics i.e. crown diameter and canopy spread were best in strawberry plants grown in open field and treated with 450 ppm GA3 solution. Hence it can be concluded that strawberries cultivated in a lath house and sprayed with 450 ppm GA3 produced excellent quality plants and capable to produce runners for the next season.

The results obtained from this study will be helpful in producing runners locally under Rawalpindi /Islamabad condition which will save the time and foreign exchange to be spent on runner import/propagation of Strawberry and in turn will also lower the production cost. From this experiment it can recommended that strawberry crop must be grown in a lath house and sprayed with 450 ppm GA3 solution to improve vegetative qualities and to raise strawberry nursery from the standing crop.

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Data Availability Statement

All data and materials are available from the corresponding author. Therefore, at a reasonable request, the corresponding author shared it via email.

Competing Interests

Authors have declared that no competing interests exists

Ethical Approval: The ethical issues is not applicable

Consent of Participate: Not applicable

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