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Research Article

Influence of Organic and Inorganic Fertilizer Regimes on Growth Patterns and Antioxidants Capacity of Strawberry (*Fragaria* × *Ananassa* Duch.) cv. Chandler

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Fertilization, either in the form of organic or inorganic, always affects plant growth, yield, and nutritional quality of fruit crops. Further, the efficacy of fertilizers depends on various factors, including the area, climatic conditions, and cultivars. Rawalakot has ideal climatic conditions for growing strawberries. However, no studies related to the impact of different soil amendments on the growth habit and fruit quality of strawberries have been conducted so far. Therefore, in this study, different combinations of organic (farmyard manure (FYM) and poultry manure (PM)) and inorganic (urea) (N 150 kg/ha) fertilizers were used for comparison of growth pattern and postharvest quality of strawberry cv. Chandler. The organic and inorganic fertilizer regimes showed comparatively better results in terms of all the parameters studied. However, plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha and FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha showed 41% and 28% more survival percentage compared to control. Furthermore, the number of leaves, number of flowers, number of fruits, and yield were significantly high in plants grown on amended soil. Moreover, a significantly high amount of total soluble solids (10.0°Brix), titratable acidity (1.18%), ash (0.84%), fiber (3.03%), total phenols (7.61 μg gallic acid/g fresh weight), total flavonoids (7.93 mmol quercetin/100 g fresh weight), and total antioxidants (0.60 activity of $FeSO_4$ mg/g fresh weight) was noted in comparison with control. Similarly, a combined treatment of FYM, PM, and urea also showed good results in terms of all the growth and fruit quality parameters as compared with other fertilizer regimes as well as control. However, the overall results of this study revealed that strawberries grown on soil amended with a combined dose of FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha could be a potential dose for maximum yield and better quality fruits of strawberry.

1. Introduction

Strawberry (*Fragaria × ananassa* Duch.) is a France native berry and legendary fruit of temperate regions. It is consumed all over the world due to its striking red colour, high antioxidant activity, and low caloric values [1]. The fruit is rich in vitamin C, phosphorus, potassium, calcium, and iron [2]. Due to its high nutritious value, it is cultivated throughout the world, with China being the main producer (3.7 million tons), followed by the United States of America and Mexico [3]. In comparison to other countries, Pakistan's strawberries production (average of 609 tons/year) and yield (1055 tons from 395 hectares) are very low [4, 5]. This low yield in strawberry production is mainly caused by insufficient availability of nutrients, which are necessary for plant health [6].

Strawberry yield and quality are mainly dependent on soil fertility, mineral fertilization, and the minerals' ratio as well as on climatic factors [7]. Therefore, high yield with good quality fruits is highly correlated with sufficient nutrients for proper plant nourishment [8]. This nutrient supply could be provided through different fertilization strategies, methods, and technologies [9, 10]. Strawberries have a large harvest window with intensive nutrient uptake, which results in depletion of soil fertility [11]. Availability of nitrogen is the most important factor for its production and fruit quality [12]. In effect, vegetables and fruit produced with sufficient availability of nutrients contain a high level of total phenols, flavonoids, organic acids, sugars, and L-ascorbic acid [13].

Inorganic nitrogen sources are commonly used to manage depletion in soil fertility and sustainable crop production, but their cost and additional constraints discourage small growers from using them [14]. The availability of nitrogen from inorganic sources during early crop growth is higher than the plant demand and leads to potential nitrogen losses. In addition, excessive use of inorganic fertilizer (IF) on fruits which are eaten with peel could be harmful to human health [15]. Consequently, organic fertilizer (OF) inputs are necessary to preserve soil organic matter and increase crop productivity. Organic supplements increase available nitrates, soil enzymes activity, metabolic quotients, and the ratio of carbon to total organic carbon ensuing in improved soil fertility [16]. The use of OF is also helpful in increasing plant resistance against nutrient deficiency which results in regulation of different physiological processes such as decreased lipid peroxidation, increased osmotic regulation, and high antioxidant enzymes activity [6]. Thus, the combined effect of IF and OF not only is helpful in overcoming the nutrients deficiency in soils but also has very significant effects on food production worldwide [17].

Among OF, poultry manure (PM) and farmyard manure (FYM) serve as excellent soil amendments which provide nutrients for crop growth and improve soil quality when applied sensibly. PM is helpful in improving soil structure such as aeration, water holding capacity, nutrition retention, and water infiltration [18]. Since FYM and PM have high organic matter content collectively, excessive nutrients could be provided to the plants for their better growth [19]. A range of IF and OF has been studied on strawberry in Turkey, and the results suggested that OF improved strawberry colour and antioxidant properties, but still IF was required for high yield [20]. Furthermore, it has also been observed that the efficacy of OF and IF is changed with area, climatic conditions, and cultivars [20]. However, still very little is known about the impact of soil amendments on growth habit and fruit quality using OF and IF before transplanting strawberry plants.

Table 1: Physical and chemical properties of different organic and inorganic fertilizers and soil before planting strawberry runners.

Parameters	Decomposed FYM	Decomposed PM	Urea	Soil
Organic carbon (%)	41.39	31.32	—	0.32
Nitrogen (%)	1.21	2.60	46.0	0.018
C/N ratio	34.00	12.00	—	17.70
P_2O_5 (%)	0.24	1.70	—	5.87
K_2O (%)	2.10	1.20	—	95.97
Ca (%)	0.81	1.46	—	0.82
Mg (%)	0.34	0.61	—	0.067
pH	7.20	5.70	—	7.40

Therefore, this experiment aimed to assess the management of IF and OF regimes through FYM, PM, and urea on the growth habit of strawberry cv. Chandler. Furthermore, fruit quality parameters (total soluble solids, titratable acidity, and pH) and health-promoting metabolites (anthocyanins, phenolics, flavonoids, and antioxidants) were also studied.

2. Materials and Methods

2.1. Experimental Details and Plant Material. The current study was completed in two seasons (March–July 2019 and March–July 2020) in the experimental field of the Department of Horticulture, Faculty of Agriculture, University of Poonch, Rawalakot, Azad Jammu and Kashmir (latitude 33–36°N and longitude 73–75°E). During the study, different organic and inorganic fertilizers were used for growing strawberry cv. Chandler. Strawberry runners of commercially grown cv. Chandler were bought from the National Agriculture Research Center (NARC), Islamabad, and shifted to 12-inch plastic pots. Based on previous reports, different OF and IF were used as N source (150 kg N per ha). Eight different OF and IF doses either alone or in combination (urea 150 kg N per ha; FYM equivalent to 150 kg N per ha; PM equivalent to 150 kg N per ha; FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha) were used. No fertilizer treatment was applied in the control pots. Five pots per replicate were filled in with sand and clay in a 1 : 1 ratio. The respective treatments were applied one day before transplanting runners. One runner per pot was planted on 15th March of each year.

2.2. Field Site Description. Plastic pots (12 inches) were used to transplant strawberry runners. These pots were placed at the experimental field at Rawalakot. Polyethylene sheet having 200 μm PE was used to provide shade to these potted plants. To get healthy plants and good quality fruits, all essential agronomic practices such as manual weeding and irrigation (200 ml per pot) were done twice a week. Soil and manure analyses were done before commencing the experiment, and the results are presented in Table 1. After the application of various organic fertilizer (OF) and inorganic fertilizer (IF) treatments, data regarding vegetative and reproductive growth and postharvest quality parameters of strawberry were noted as stated in the following.

2.3. Vegetative and Reproductive Growth Parameters. Data collection for vegetative and reproductive growth parameters was done by selecting 15 plants from each treatment. Vegetative and reproductive growth was determined by several parameters. Survival percentage was calculated one month after transplanting of runners by dividing the number of plants survived by the total number of plants transplanted. Number of leaves and number of runners from each plant were counted at the end of the experiment. Days to first flower, number of flowers, number of fruits, days to harvest, and yield (g) were counted according to the methods given by Zahid et al. [1]. Destructive sampling of leaves was done for computation of chlorophyll a and b and total chlorophyll [21]. Fruit weight (g) was measured by using a digital weighing balance (Model: Shimadzu A ×20), whereas fruit diameter (cm) was measured by using a Vernier caliper (Model: Insize SR44).

2.4. Postharvest Fruit Quality Parameters. Strawberry fruits (300 g) were taken from each treatment, placed in polyethylene zip lock bags, and brought to the postgraduate laboratory. Total soluble solids (TSS) were determined according to the Association of Official Analytical Chemists [22] using a digital refractometer (Kyoto Company, Japan) at room temperature. Results were expressed as °Brix. Titratable acidity (TA) was measured by using 5 g of fruit pulp, homogenized with 20 ml of purified water, and filtered to obtain a pure extract. Each extract (5 ml) was titrated against sodium hydroxide solution (0.1 N) using a phenolphthalein indicator. Results obtained were expressed in the percentage of ascorbic acid. Fruit juice was used to measure pH with a pH meter (Model: WTW 82362, Inolab, Germany) according to AOAC [23]. Strawberry fruits (5 g) were dried for 3 hours in a muffle furnace (Model: SX-2-5-10) at 600°C. Difference in fresh weight and dried weight was considered as ash contents [24]. Fiber (%) was measured by the standard method of AOAC [25]. Fruit sample (5 g) was dried in a hot oven until constant weight followed by digestion with sulphuric acid (1.25%) and sodium hydroxide (1.25%), respectively. The digested sample was washed with purified water and again put in a furnace at 500 or 550°C until white ash was obtained. A gallic acid standard curve (0–1.5 mg per ml) was used to measure total phenols in strawberry fruit as given by Maqbool et al. [26]. Fruit extract (0.1 ml) plus

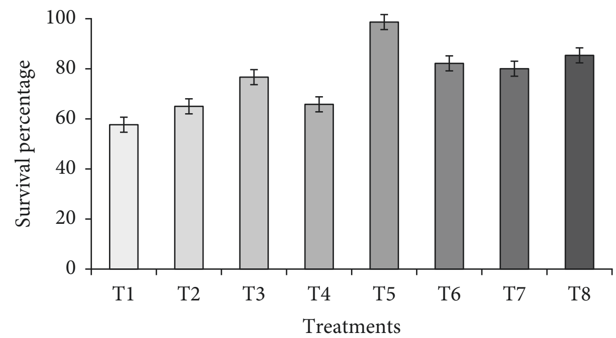

Figure 1: Influence of different organic and inorganic fertilizer regimes on survival percentage (%) of strawberry cv. Chandler. T_1: control; T_2: urea 150 kg N per ha; T_3: FYM equivalent to 150 kg N per ha; T_4: PM equivalent to 150 kg N per ha; T_5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T_6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. ± SEM.

Folin–Ciocalteu's phenol reagent (0.5 ml) plus sodium carbonate (1.5 ml) was mixed and incubated in the dark for two hours. Absorbance of the mixture was then measured at 750 nm using a spectrophotometer (Model: UV 4000, ORI, Reinbeker, Hamburg, Germany). The results obtained were presented as equivalents μg gallic acid per g of fruit weight. Methanolic $AlCl_3.6H_2O$ was used to measure total flavonoids according to the method given by Ali et al. [27]. Strawberry pulp (0.5 mg) was mixed with methanolic $AlCl_3.6H_2O$ in sealed tubes. The mixture was allowed to react for 15 min in the dark. Absorbance of the mixture was then measured at 430 nm using the spectrophotometer described above. Results obtained were presented as mmol of quercetin per 100 g fresh weight of fruit. Vitamin C was measured by using 2,6-dichlorophenol indophenol dye according to AOAC [28]. Sample extract (100 ml) was mixed with 5 ml of metaphosphoric acid solution (4%) and titrated with 2,6-dichlorophenol indophenol dye until a light pink colour appeared as an endpoint. Total anthocyanins were measured by using two pH dilutions [29]. Sodium acetate buffer (pH 4.5) and potassium chloride buffer (pH 1.0) were prepared. Absorbance of all samples was measured at 700 and 510 nm, using a spectrophotometer. Results obtained were presented as mg of cyanidin-3-glucoside per 100 g fresh weight of fruit. Total antioxidants were calculated by using ferric reducing antioxidant power (FRAP) assay. The fruit juice (40 μl) was added to 3 ml of FRAP reagent and incubated in the dark (37°C) for 4 min. Absorbance of all samples was measured at 593 nm, and the results were presented as the activity of $FeSO_4$ mg per g fresh weight of fruit.

2.5. Statistical Analyses. A randomized complete block design (RCBD) was used for this experiment. The experiment was laid out with three replicates and repeated twice. Data were combined for analysis as no significant differences were observed between trails. Statistix 8.1 [30] software was used

Table 2: Influence of different organic and inorganic fertilizer regimes on vegetative and reproductive growth of strawberry cv. Chandler.

Treatment	No. of leaves per plant	No. of runners per plant	Days to first flower	No. of flowers	No. of fruits	Days to harvest	Yield (g)
T_1	7.46 ± 0.75 c	14.33 ± 0.48 c	49.87 ± 0.46 a	13.26 ± 0.90 d	12.36 ± 0.32 d	117.83 ± 0.56 a	167.60 ± 0.93 f
T_2	10.53 ± 0.90 bc	15.50 ± 0.76 bc	47.06 ± 0.73 a	15.63 ± 0.75 c	12.96 ± 0.71 d	114.06 ± 0.73 b	183.51 ± 0.89 e
T_3	11.40 ± 0.53 bc	16.43 ± 0.81 bc	44.32 ± 0.32 a	18.20 ± 0.70 b	14.06 ± 0.52 c	110.32 ± 0.32 c	214.13 ± 1.72 d
T_4	10.76 ± 1.53 bc	17.33 ± 0.66 bc	48.99 ± 0.57 a	16.13 ± 1.15 c	14.06 ± 0.60 c	111.99 ± 0.67 c	213.71 ± 1.86d
T_5	16.46 ± 0.35 a	25.16 ± 1.20 a	43.65 ± 0.23 a	20.00 ± 0.58 a	17.10 ± 0.52 a	100.07 ± 0.44 f	313.44 ± 4.14 a
T_6	12.00 ± 1.15b	18.76 ± 1.02 bc	42.07 ± 0.40 a	17.96 ± 1.44b	15.06 ± 0.49 ab	107.11 ± 0.61d	254.51 ± 4.05 c
T_7	11.66 ± 0.88b	17.46 ± 1.24 bc	45.66 ± 0.38 a	17.80 ± 1.10b	16.16 ± 0.41 ab	105.66 ± 0.38d	286.51 ± 2.05b
T_8	12.93 ± 0.69b	20.46 ± 1.11b	46.87 ± 0.26 a	18.33 ± 1.13b	15.86 ± 0.46 ab	102.81 ± 0.26 e	277.55 ± 3.65b

T_1: control; T_2: urea 150 kg N per ha; T_3: FYM equivalent to 150 kg N per ha; T_4: PM equivalent to 150 kg N per ha; T_5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T_6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. Different letters show significant ($P < 0.05$) differences in treatments using Tukey's test, ± SEM.

for analysis of variance (ANOVA), and means were separated by using Tukey's test ($\alpha = 0.05$).

3. Results

3.1. Plant Growth Patterns. Different OF and IF showed significant ($P < 0.05$) effects on the growth patterns of strawberry cv. Chandler. Survival percentage is shown in Figure 1. The highest survival percentage was observed in those plants grown on soil amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha (98.6%) followed by the plants grown on soil amended with FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha (85.36%). On the other hand, the lowest survival percentage (57.6%) was recorded for the control plants. Similarly, the maximum number of leaves per plant (16.46) was observed in the plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, which was significantly ($P < 0.05$) different from the control plants (7.46) (Table 2).

Significant ($P < 0.05$) differences were also recorded for the number of runners per plant, with the maximum (25.16) recorded in the plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha and the lowest number of runners per plant (14.33) found in the control plants (Table 2).

Table 2 also shows the number of days to first flower (42 to 50), which was similar for all the treatments ($P > 0.05$). On the contrary, significant differences ($P < 0.05$) were recorded for the number of flowers and the number of fruits per plant. The maximum number of flowers (20.0) and fruits (17.10) per plant were recorded in plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, while the minimum number of flowers (13.26) and fruits (12.36) per plant were recorded in control plants (Table 2).

Significant differences ($P < 0.05$) were recorded for days to harvest and yield of strawberries cv. Chandler (Table 2). Strawberry plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha took the minimum number of days to fruit harvest (100.07), while the maximum number of days to fruit harvest (117.83) were noted in control plants. Similarly, the highest yield per plant (313.44 g) was noted in plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, while the lowest yield was noted in control plants (167.60 g) (Table 2).

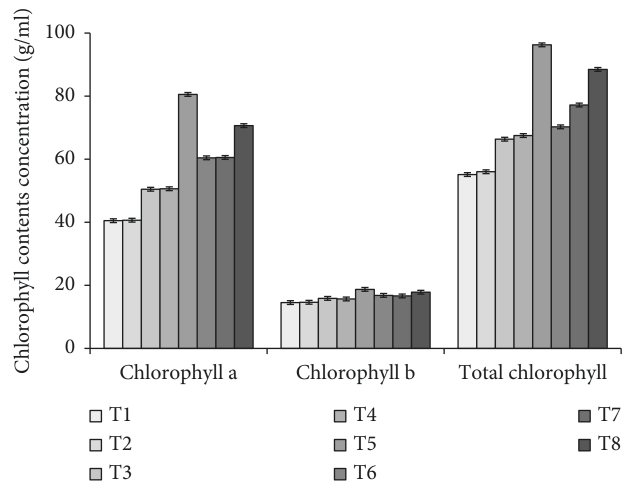

Figure 2: Influence of different organic and inorganic fertilizer regimes on chlorophyll contents (g/ml) of strawberry cv. Chandler. T1: control; T2: urea 150 kg N per ha; T3: FYM equivalent to 150 kg N per ha; T4: PM equivalent to 150 kg N per ha; T5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. ± SEM.

The chlorophyll content of the strawberries is shown in Figure 2. Maximum chlorophyll a and b and total chlorophyll content were found in the plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, followed by plants treated with FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. The lowest chlorophyll a and b and total chlorophyll were recorded in control plants.

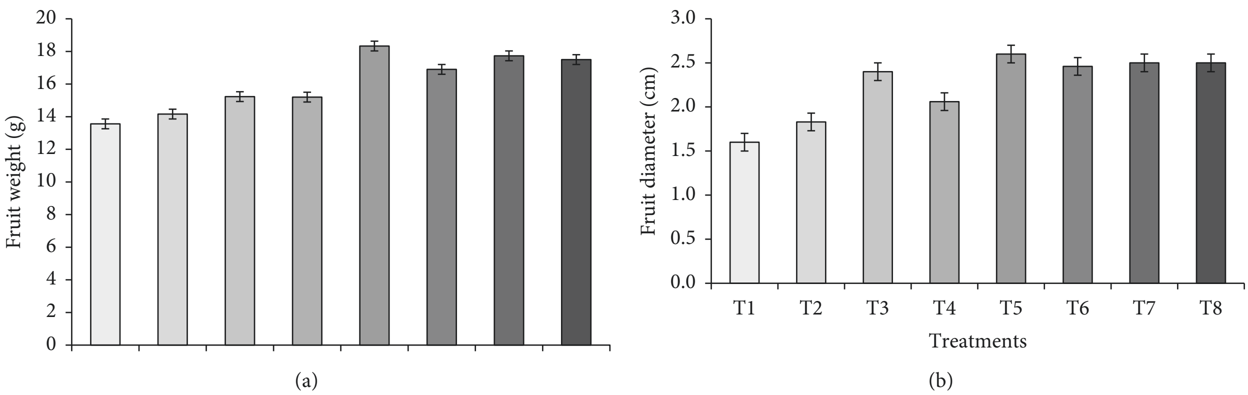

FIGURE 3: Influence of different organic and inorganic fertilizer regimes on (a) fruit weight (g) and (b) fruit diameter (cm) of strawberry cv. Chandler. T1: control; T2: urea 150 kg N per ha; T3: FYM equivalent to 150 kg N per ha; T4: PM equivalent to 150 kg N per ha; T5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. ± SEM.

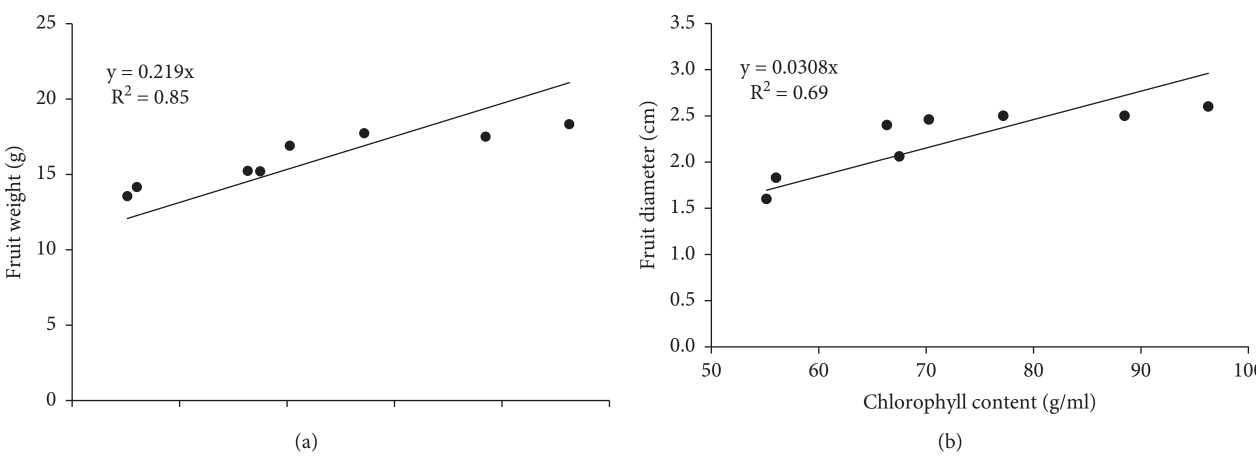

FIGURE 4: Correlation between chlorophyll contents (g/ml) (a) fruit weight (g) and (b) fruit diameter (cm) of strawberry cv. Chandler at $P < 0.05$.

3.2. Fruit Postharvest Quality. The different fertilizers used provoked significant differences ($P < 0.05$) in the fruit weight and fruit diameter of the strawberries (Figures 3(a) and 3(b)). Maximum fruit weight (18.33 g) was recorded in plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, while minimum fruit weight was noted in control plants (13.56 g) (Figure 3(a)). Results regarding fruit diameter showed that plants grown on soil amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha had the biggest fruits in comparison with all the other treatments (Figure 3(b)). Results of fruit weight and fruit diameter were correlated with total chlorophyll content (Figures 4(a) and 4(b)). In effect, 1 unit rise in total chlorophyll content led to a 0.219-fold rise in fruit weight (Figure 4(a)) and a 0.0308-fold rise in fruit diameter (Figure 4(b)).

Quality parameters of the strawberries are presented in Table 3. The plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha had the maximum total soluble solids (TSS) (10.0°Brix), titratable acidity (TA) (1.18%), ash content (0.84%), and crude fiber content (3.03%), together with the lowest pH (3.43), while the opposite was observed in the fruit from the control plants.

Significant differences ($P < 0.05$) were noticed among the fruits of all treated plants in terms of secondary metabolites (Figures 5(a)–5(e)). Fruits obtained from plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha showed the highest amount of total phenolics (7.61 μg gallic acid/g fruit weight) (Figure 5(a)), total flavonoids (7.93 mmol quercetin/100 g fruit weight) (Figure 5(b)), vitamin C (38.42 mg/100 g fruit weight) (Figure 5(c)), total anthocyanins (3.89 mg cyaniding-3-glucoside/100 g fruit weight) (Figure 5(d)), and total antioxidants (0.60 mg activity of $FeSO_4$/g fresh weight) (Figure 5(e)), while the minimum amount of secondary metabolites was noted in fruits collected from control plants.

4. Discussion

4.1. Plant Growth Patterns. Generally, plant growth increases with the application of fertilizers. Both OF and IF serve as a source of mineral nutrition for plants [31].

Table 3: Influence of different organic and inorganic fertilizer regimes on postharvest quality of strawberry cv. Chandler.

Treatments	TSS (°Brix)	TA (%)	pH	Ash (%)	Fiber (%)
T_1	4.93 ± 0.76 c	0.84 ± 0.04b	4.09 ± 0.14 a	0.49 ± 0.01 f	1.71 ± 0.06 e
T_2	5.46 ± 0.87 c	1.03 ± 0.02 ab	3.87 ± 0.11b	0.57 ± 0.07 e	1.94 ± 0.07d
T_3	6.00 ± 0.78 bc	0.87 ± 0.03b	3.77 ± 0.06 c	0.69 ± 0.01d	2.19 ± 0.07 c
T_4	6.76 ± 0.43 abc	0.92 ± 0.04b	3.69 ± 0.17d	0.71 ± 0.02d	2.06 ± 0.09cd
T_5	10.00 ± 0.58 a	1.18 ± 0.06 a	3.43 ± 0.04 f	0.84 ± 0.04 a	3.03 ± 0.10 a
T_6	7.60 ± 0.31 abc	0.94 ± 0.04b	3.76 ± 0.09 c	0.76 ± 0.02 c	2.38 ± 0.08b
T_7	7.73 ± 0.88 abc	0.95 ± 0.06 ab	3.66 ± 0.10d	0.77 ± 0.02 c	2.59 ± 0.09b
T_8	9.26 ± 0.19 ab	1.05 ± 0.05 ab	3.58 ± 0.06 e	0.81 ± 0.03b	2.78 ± 0.08 ab

TSS: total soluble solids; TA: titratable acidity; T_1: control; T_2: urea 150 kg N per ha; T_3: FYM equivalent to 150 kg N per ha; T_4: PM equivalent to 150 kg N per ha; T_5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T_6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T_8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. Different letters show significant ($P < 0.05$) differences in treatments using Tukey's test, ± SEM.

However, the optimum amount of nitrogen is helpful in the growth of plants; nevertheless, the required amounts of mineral nutrients to plants differ with plant species, cultivar, and expected yield [32]. In our results, the highest rate of survival was observed in plants grown on soil amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, which might be due to the optimum amount of nitrogen that is required for stable crop production. This high survival rate could be due to the availability of micro- and macronutrients such as nitrogen, potassium, phosphorus, calcium, and magnesium in FYM and PM [18]. Surplus supply of nitrogen to the plants showed adverse effects on plant health and led to plant death [33]. OF are responsible for increased soil porosity by reducing bulk density which results in increased water retention [34]. This increased water retention is helpful for better uptake of nutrients which results in an increased survival rate [35].

Soil physical properties are improved with the application of OF, which in turn plays a positive role in nutrients uptake from soil and improves the growth patterns of plants [11]. In our results, the increased number of leaves and runner production in plants matured on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha could be due to the fact that those soils contained a handsome amount of soil organic carbon and micro- and macronutrients which were essential for the sustainable vegetative growth [36]. In an earlier study, it was stated that the integrated application of nutrient sources in soil resulted in increased flowers and fruits [37]. Therefore, the highest number of flowers and fruits on plants grown on soil amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha was due to the quantum of N, P, K, and other hormones present in OF. They played a vital role in the production of gibberellic acid in roots which helped in breaking bud dormancy, which resulted in enhanced bud production and increased flowering sites [36]. It has also been reported that reduced amounts of phosphorus in the soil at the time of flower production led to reduced flower size and aborted female flower parts, which resulted in less fruit setting [38]. It has been reported that IF is leached down from the soil and unavailable to the plants, whereas the nutrient availability of OF is slow, which helps in increased yield [36]. Nitrogen from urea undergoes chemical transformation, either NO^{3-} or NH^{4+}, and this NO^{3-} is extremely mobile and tends to leach down within 3 to 15 days of application [39]. Whereas the soil nitrogen contents increased with the use of FYM and other OF, this might be due to slow decomposition of organic matter which results in slow release of nitrogen [40]. Overall, the yield of strawberry depends on the growth medium [1]. In our results, the maximum yield was obtained from the plants grown on soil amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha, which helped in not only increasing the fruiting site but also early onset of reproductive stage [41].

Increased chlorophyll contents may result in more photosynthesis, thus increasing crop growth and yield [42]. Nitrogen is the constituent of chlorophyll, slow availability of nitrogen to plants helps in more chlorophyll production [31], and the organic forms of nitrogen are more effective in this regard [43]. More chlorophyll contents result in more fruit weight and fruit diameter due to more photosynthesis [1]. During fruit ripening, fruits possess a sink for nitrogen and potassium, and our results showed that FYM and PM were rich in these essential nutrients (Table 1). This relationship of increased nitrogen and potassium resulted in increased fruit weight and fruit diameter [1].

4.2. Fruit Postharvest Quality. Nutrient quality of strawberries varies with different genotypes and nutritional composition of soil [44]. High acidity and more soluble solids are liable for good taste [44]. The amount of total soluble solids and acidity varies in different strawberry genotypes [46]. High foliage of plants with the use of organic manure helps in keeping berry temperature low, thus resulting in less acid loss during respiration [47]. In our results, plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha showed the most promising results, which might be due to the slow release of nutrients from OF.

The variation in nutrient composition of strawberries depends on the availability of nutrients to the plants during fruit production [35]. It was reported that the application of FYM in soils resulted in an increased chlorophyll production which helped in increased assimilates production and was responsible for increased soluble solid contents [47].

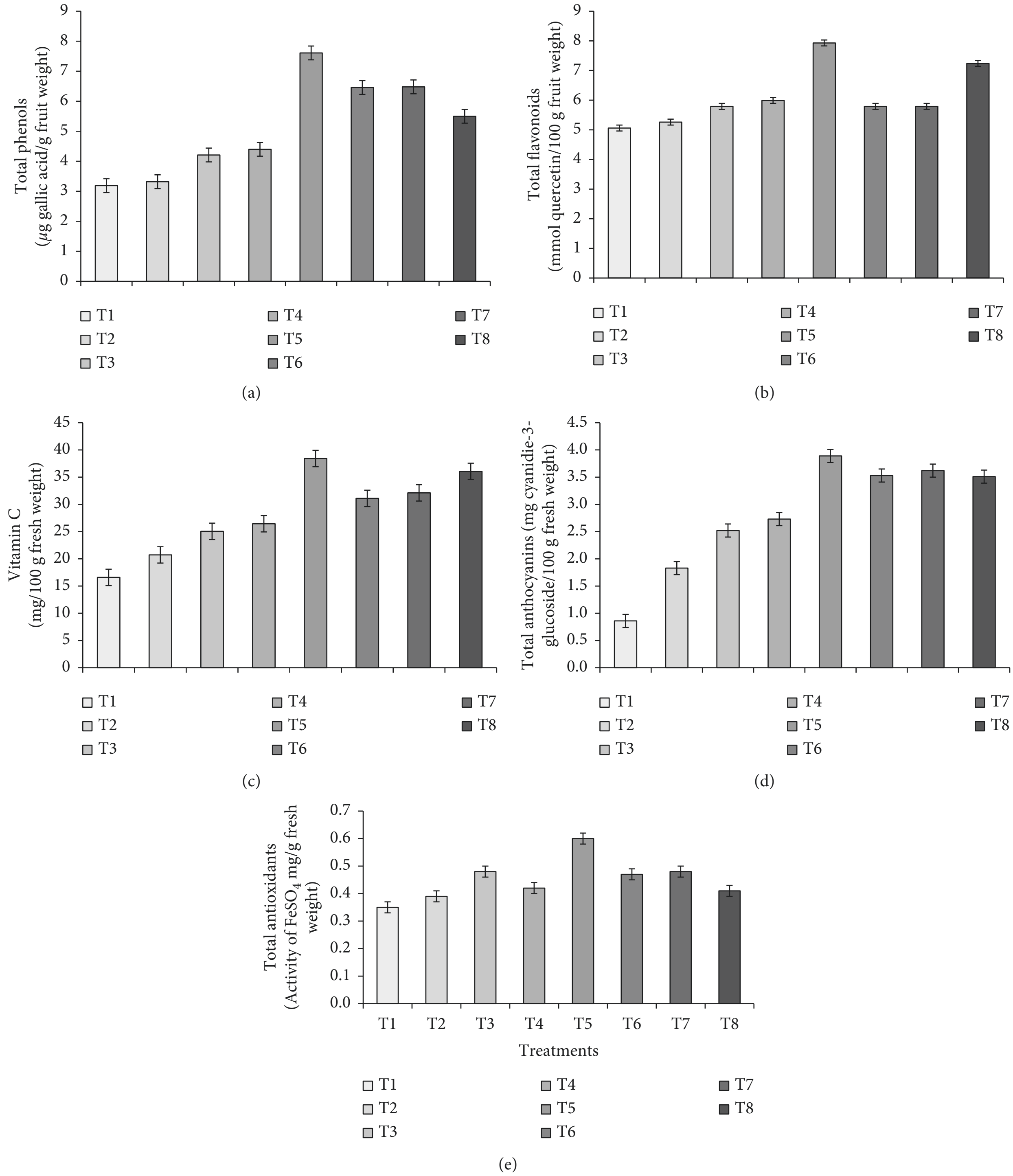

Figure 5: Influence of different organic and inorganic fertilizer regimes on (a) total phenols (μg gallic acid/g fruit weight), (b) total flavonoids (mmol quercetin/100 g fruit weight), (c) vitamin C (mg/100 g fresh weight), (d) total anthocyanins (mg cyanidin-3-glucoside/100 g fresh weight), and (e) total antioxidants (activity of FeSO4 mg/g fresh weight) of strawberry cv. Chandler. T1: control; T2: urea 150 kg N per ha; T3: FYM equivalent to 150 kg N per ha; T4: PM equivalent to 150 kg N per ha; T5: FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha; T6: FYM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T7: PM equivalent to 75 kg N per ha + urea equivalent to 75 kg N per ha; T8: FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha. ± SEM.

Results regarding moisture, ash, and fiber contents are connected to the sugar contents, which are liable for ascorbate synthesis. Ascorbate acts as a precursor for the assimilation of these nutrients [35]. A recent study by our group reported that phosphorus played a significant role in the gathering of sugars and transferred energy to maintain this biochemical phase [1]. Current results showed that fruits selected from plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha revealed the most promising results in terms of fiber and ash contents which might be due to the presence of phosphorus in FYM and PM.

Total phenols, flavonoids, vitamin C, anthocyanin, and total antioxidants are mostly considered as health-related compounds [47]. Strawberries are rich in polyphenols, and these phenolic compounds are highly dependent on soil fertility and the amount of fertilizer used [49]. Differences in total phenolic contents of strawberry could be due to the fact that diverse bacteria present in organic manures help plants in fixing nitrogen from air and produce different phytohormones such as phenolics [50]. Supplementary phosphorus and potassium present in FYM and PM helped in more nitrogen-fixing activity of different bacteria, which resulted in increased total phenolic contents in fruits [49]. In a previous study, the amount of total phenols increased 30-fold with the use of FYM [51].

Total flavonoids are important secondary metabolites which not only act as antioxidants for the human body but also lessen over ripening in fruits [1]. Moreover, the accumulation of flavones and flavanols defends plants against different biotic and abiotic stresses [52]. The use of organic manure induces the acetate shikimate pathway, which results in higher production of flavonoids [53]. Several studies showed that the amount of flavonoids depends on light intensity and the rate of photosynthesis [53–57]. Thus, the increase in chlorophyll contents in plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha resulted in an increased photosynthetic rate which influenced the amount of total flavonoids in fruits.

Vitamin C and total anthocyanins are the most significant health-promoting compounds. Generally, it is stated that vitamin C is a tissue-specific and genetic factor [57]. However, the synthesis of these compounds is anabolic and follows $_{L}$-galactose pathway, which is photosynthesis dependent [35]. Maximum chlorophyll contents were observed in plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha and resulted in a high amount of vitamin C content in fruits which might be due to the high photosynthesis rate [46]. Moreover, potassium present in the soil also helps in increased vitamin C content in fruits [58].

Total antioxidants are highly correlated with phenols, flavonoids, and anthocyanins present in fruits [53]. The high amount of phenols, flavonoids, and anthocyanins results in high antioxidant activity, which sanctions the theory that the growing media of any crop is highly beneficial for antioxidant activity [60]. However, in this study, the highest nutritional content in strawberries grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha confirms that organic manures provide better nutrition to the plants' development and assimilation of nutritional compounds.

5. Conclusions

This study concludes that strawberry plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha had shown significant improvement in the growth of strawberry cv. Chandler as compared with control. Further, a combined treatment of FYM, PM, and urea also showed good results in terms of all the growth and fruit quality parameters as compared with other fertilizer regimes as well as control. However, in case of IF, the lesser efficacy could be due to the fast leaching of nitrogen, which resulted in lower uptake of nitrogen to the plants. Based on the results of this study, it is recommended that combined treatment of FYM and PM should be used for growing strawberries in future. However, further studies are required to test different varieties of strawberries using various combinations of organic and inorganic fertilizers under open field conditions.

Data Availability

The data have been given in the paper. If any other details are needed, we will be happy to provide that.

Disclosure

Noosheen Zahid's current address is the Department of Horticulture, Faculty of Agriculture, University of Poonch, Rawalakot, Azad Jammu and Kashmir, Pakistan.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

[1] N. Zahid, M. Maqbool, A. Hamid et al., "Changes in vegetative and reproductive growth and quality parameters of strawberry (*Fragaria × ananassa* Duch.) cv. Chandler grown at different substrates," *Journal of Food Quality*, vol. 2021, Article ID 9996073, 9 pages, 2021.

[2] A. K. Das, K. P. Singh, B. Prasad, and R. Kumar, "Evaluation of cultivars of strawberry, a temperate fruit for its adaptability as well as productivity in sub-tropical agro-climatic condition of Supaul district in Bihar," *The Asian Journal of Horticulture*, vol. 10, no. 2, pp. 278–281, 2015.

[3] A. Ali, A. Ghafoor, M. Usman et al., "Valuation of cost and returns of strawberries in Punjab Pakistan," *Pakistan Journal of Agricultural Sciences*, vol. 58, pp. 283–290, 2021.

[4] M. M. Aziz, R. S. Amina, M. M. Abbas, and S. Riaz, "Evaluation of strawberry (*Fragaria ananassa* Duch.) cultivars for morphological and physicochemical parameters in subtropical climate," *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, vol. 34, pp. 126–129, 2018.

[5] GOP, *Fruits, Vegetables and Condiments Statistics of Pakistan*, Ministry of Food Agriculture and Economics Division, Rome, Italy, 2019.

[6] R. Anwar, S. Gull, M. Nafees et al., "Pre-harvest foliar application of oxalic acid improves strawberry plant growth and

fruit quality," *Journal of Horticultural Science & Technology*, vol. 1, pp. 35–41, 2018.
[7] G. Tohidloo, M. K. Souri, and S. Eskandarpour, "Growth and fruit biochemical characteristics of three strawberry genotypes under different potassium concentrations of nutrient solution," *Open Agriculture*, vol. 3, no. 1, pp. 356–362, 2018.
[8] S. Agehara and M. C. d. N. Nunes, "Season and nitrogen fertilization effects on yield and physicochemical attributes of strawberry under subtropical climate conditions," *Agronomy*, vol. 11, no. 7, pp. 1391–1404, 2021.
[9] Z. A. Forotaghe, M. K. Souri, M. G. Jahromi, and A. M. Torkashvand, "Physiological and biochemical responses of onion plants to deficit irrigation and humic acid application," *Open Agriculture*, vol. 6, no. 1, pp. 728–737, 2021.
[10] F. Serri, M. K. Souri, and M. Rezapanah, "Growth, biochemical quality and antioxidant capacity of coriander leaves under organic and inorganic fertilization programs," *Chemical and Biological Technologies in Agriculture*, vol. 8, pp. 1–8, 2021.
[11] M. H. M. Mohamed, S. A. Petropoulos, and M. M. E. Ali, "The application of nitrogen fertilization and foliar spraying with calcium and boron affects growth aspects, chemical composition, productivity and fruit quality of strawberry plants," *Horticulturae*, vol. 7, no. 8, pp. 257–273, 2021.
[12] S. Agehara, "Characterizing early-season nitrogen fertilization rate effects on growth, yield, and quality of strawberry," *Agronomy*, vol. 11, no. 5, pp. 905–917, 2021.
[13] Y. Wu, L. Li, M. Li, M. Zhang, H. Sun, and N. Sigrimis, "Optimal fertigation for high yield and fruit quality of greenhouse strawberry," *PLoS One*, vol. 15, no. 4, Article ID e0224588, 2020.
[14] T. Bayu and F. Li, "Review on contribution of integrated soil fertility management for climate change mitigation and agricultural sustainability," *Cogent Environmental Science*, vol. 6, p. 1, 2020.
[15] J. Campbell, A. Sarkhosh, F. Habibi et al., "Evaluation of biochemical juice attributes and color-related traits in Muscadine grape population," *Foods*, vol. 10, no. 5, p. 1101, 2021.
[16] A. Piotrowska-Długosz, J. Długosz, A. Gryta, and M. Frąc, "Responses of N-cycling enzyme activities and functional diversity of soil microorganisms to soil depth, pedogenic processes and cultivated plants," *Agronomy*, vol. 12, pp. 264–290, 2022.
[17] M. Zhang, D. Sun, Z. Niu, J. Yan, X. Zhou, and X. Kang, "Effect of combined organic/inorganic fertilizer application on growth, photosynthetic characteristics, yield and fruit quality of *Actinidia chinesis* cv 'Hongyang," *Global Ecology and Conservation*, vol. 22, Article ID e00997, 2020.
[18] K. Sharma and M. Negi, "Effect of organic and inorganic fertilizers on plant growth of strawberry (*Fragaria × ananassa*) cv. Shimla delicious under mid-hill conditions of Uttarakhand," *Journal of Pharmacognosy and Phytochemistry*, vol. 8, no. 2, pp. 1440–1444, 2019.
[19] V. Nand, R. K. Gupta, R. S. Yadav, K. D. Singh, R. K. Yadav, and A. K. Srivastav, "Impact of integrated nutrient management (INM) on growth of Barseem (*Trifolium alexandrinum* L.) at various cutting stages," *Journal of Pharmacognosy and Phytochemistry*, vol. 4, pp. 254–258, 2018.
[20] N. Kilic, A. Burgut, M. A. Gündesli et al., "The effect of organic, inorganic fertilizers and their combinations on fruit quality parameters in strawberry," *Horticulturae*, vol. 2021, p. 14, Article ID 7100354, 2021.
[21] N. Zahid, A. Ali, S. Manickam, Y. Siddiqui, P. G. Alderson, and M. Maqbool, "Efficacy of curative applications of submicron chitosan dispersions on anthracnose intensity and vegetative growth of dragon fruit plants," *Crop Protection*, vol. 62, pp. 129–134, 2014.
[22] AOAC, *Official Method of Analysis 960.20: Total Soluble solids. Official Methods of Analysis of the Association of Chemists*, Analysis of the Association of Chemists, Washington, DC, USA, 1990.
[23] AOAC, *Official Method of Analysis 994.16: pH. Official Methods of Analysis of the Association of Chemists*, Analysis of the Association of Chemists, Washington, DC, USA, 1990.
[24] AOAC, "Official method of analysis 940.26: ash of fruits," in *Association of Official Analytical Chemists*, S. Williams, Ed., vol. 2p. 7, 16th edition, Publication by AOAC International, Rockville, MD, USA, 1998.
[25] AOAC, *Official Method of Analysis 978.10: Crude fiber. Official Methods of Analysis of the Association of Chemists*, Analysis of the Association of Chemists, Washington, DC, USA, 1990.
[26] M. Maqbool, N. Zahid, A. Hamid et al., "Evaluation of physico-nutritional and functional properties of indigenous pear cultivars grown in Rawalakot, Azad Jammu and Kashmir," *Pakistan Journal of Agricultural Sciences*, vol. 56, pp. 607–611, 2019.
[27] A. Ali, N. Zahid, S. Manickam, Y. Siddiqui, and P. G. Alderson, "Double layer coatings: a new technique for maintaining physico-chemical characteristics and antioxidant properties of dragon fruit during storage," *Food and Bioprocess Technology*, vol. 7, no. 8, pp. 2366–2374, 2014.
[28] AOAC, *Official Method of Analysis 967.22: Vitamin C. Official Methods of Analysis of the Association of Chemists*, Analysis of the Association of Chemists, Washington, DC, USA, 1990.
[29] Y. Zheng, Y. S. Wang, and W. Zheng, "Changes in strawberry phenolics, anthocyanins and antioxidant capacity in response to high oxygen treatments," *Journal of Food Science and Technology*, vol. 40, pp. 49–57, 2007.
[30] R. G. D. Steel, J. H. Torrie, and D. A. Dickey, *Principles and Procedures of Statistic: A Biometrical Approach*, McGraw-Hill Publishing Co, Boston, MA, USA, 3rd edition, 1997.
[31] E. D. Purbajanti, W. Slamet, E. Fuskhah, and Rosyida, "Effects of organic and inorganic fertilizers on growth, activity of nitrate reductase and chlorophyll contents of peanuts (Arachis hypogaea L.)," *IOP Conference Series: Earth and Environmental Science*, vol. 250, Article ID 012048, 2019.
[32] S. Mardanluo, M. K. Souri, and M. Ahmadi, "Plant growth and fruit quality of two pepper cultivars under different potassium levels of nutrient solutions," *Journal of Plant Nutrition*, vol. 41, no. 12, pp. 1604–1614, 2018.
[33] L. Gu, T. Liu, J. Wang et al., "Lysimeter study of nitrogen losses and nitrogen use efficiency of Northern Chinese wheat," *Field Crops Research*, vol. 188, pp. 82–95, 2016.
[34] T. M. Agbede, S. O. Ojeniyi, and A. J. Adeyemo, "Effect of poultry manure on soil physical and chemical properties, growth and grain yield of sorghum in Southwest, Nigeria," *American-Eurasian Journal of Sustainable Agriculture*, vol. 2, no. 1, pp. 72–77, 2008.
[35] P. Palencia, J. Giné Bordonaba, F. Martínez, and L. A. Terry, "Investigating the effect of different soilless substrates on strawberry productivity and fruit composition," *Scientia Horticulturae*, vol. 203, pp. 12–19, 2016.
[36] R. Kumar, P. Bakshi, M. Singh et al., "Organic production of strawberry: a review," *International Journal of Chemical Studies*, vol. 6, no. 3, pp. 1231–1236, 2018.
[37] T. Odongo, D. K. Isutsa, and J. N. Aguyoh, "Effects of Integrated nutrient sources on growth and yield of strawberry

grown under tropical high altitude conditions," *The African Journal of Horticultural Science*, vol. 1, pp. 53–69, 2008.

[38] M. Tagliavini, E. Baldi, P. Lucchi et al., "Dynamics of nutrients uptake by strawberry plants (Fragaria × Ananassa Dutch.) grown in soil and soilless culture," *European Journal of Agronomy*, vol. 23, no. 1, pp. 15–25, 2005.

[39] L. Omar, O. H. Ahmed, and N. M. Majid, "Improving ammonium and nitrate release from urea using clinoptilolite zeolite and compost produced from agricultural wastes," *The Scientific World Journal*, vol. 2015, Article ID 574201, 12 pages, 2015.

[40] H. Oueriemmi, P. Kidd, C. Trasar-cepeda et al., "Evaluation of composted organic wastes and farmyard manure for improving fertility of poor sandy soils in arid regions," *Agriculture*, vol. 11, no. 5, pp. 415–434, 2021.

[41] J. F. Herencia, P. A. García-Galavís, J. A. R. Dorado, and C. Maqueda, "Comparison of nutritional quality of the crops grown in an organic and conventional fertilized soil," *Scientia Horticulturae*, vol. 129, no. 4, pp. 882–888, 2011.

[42] J. Yu, M. Wang, C. Dong et al., "Analysis and evaluation of strawberry growth, photosynthetic characteristics, biomass yield and quality in an artificial closed ecosystem," *Scientia Horticulturae*, vol. 195, pp. 188–194, 2015.

[43] M. Naiji and M. K. Souri, "Nutritional value and mineral concentrations of sweet basil under organic compared to chemical fertilization," *Acta Scientiarum Polonorum Hortorum Cultus*, vol. 17, no. 2, pp. 167–175, 2018.

[44] I. Ménager, M. Jost, and C. Aubert, "Changes in physicochemical characteristics and volatile constituents of strawberry (cv. Cigaline) during maturation," *Journal of Agricultural and Food Chemistry*, vol. 52, no. 5, pp. 1248–1254, 2004.

[45] M. M. El-Mogy, M. R. Ali, O. S. Darwish, and H. J. Rogers, "Impact of salicylic acid, abscisic acid, and methyl jasmonate on postharvest quality and bioactive compounds of cultivated strawberry fruit," *Journal of Berry Research*, vol. 9, no. 2, pp. 333–348, 2019.

[46] F. Martínez, J. A. Oliveira, E. O. Calvete, and P. Palencia, "Influence of growth medium on yield, quality indexes and SPAD values in strawberry plants," *Scientia Horticulturae*, vol. 217, pp. 17–27, 2017.

[47] I. Umar, V. K. Wali, R. Kher, and M. Jamal, "Effect of FYM, urea and Azotobacter on growth, yield and quality of strawberry cv," *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, vol. 37, no. 1, pp. 139–143, 2009.

[48] B. M. Santos and C. K. Chandler, "Influence of nitrogen fertilization rates on the performance of strawberry cultivars," *International Journal of Fruit Science*, vol. 9, no. 2, pp. 126–135, 2009.

[49] W. Sadej, A. C. Zolnowski, and O. Marczuk, "Content of phenolic compounds in soils originating from two long-term fertilization experiments," *Archives of Environmental Protection*, vol. 42, no. 4, pp. 104–113, 2016.

[50] S. M. Kern, R. N. Bennett, F. A. Mellon, P. A. Kroon, and M. T. Garcia-Conesa, "Absorption of hydroxycinnamates in humans after high-bran cereal consumption," *Journal of Agricultural and Food Chemistry*, vol. 51, pp. 6050–6055, 2003.

[51] C. Gallet, J.-M. Boissier, and M. Berlandis, "Short-term effects of manure application on soil leachates in a mountain catchment," *Agronomie*, vol. 23, no. 4, pp. 335–344, 2003.

[52] Y.-W. Ni, K.-H. Lin, K.-H. Chen, C.-W. Wu, and Y.-S. Chang, "Flavonoid compounds and photosynthesis in *Passiflora* plant leaves under varying light intensities," *Plants*, vol. 9, no. 5, p. 633, 2020.

[53] A. E.-M. M. Naguib, F. K. El-Baz, Z. A. Salama, H. Abd El Baky Hanaa, H. F. Ali, and A. A. Gaafar, "Enhancement of phenolics, flavonoids and glucosinolates of Broccoli (*Brassica olaracea*, var. Italica) as antioxidants in response to organic and bio-organic fertilizers," *Journal of the Saudi Society of Agricultural Sciences*, vol. 11, no. 2, pp. 135–142, 2012.

[54] X. Ma, L. Song, W. Yu et al., "Growth, physiological, and biochemical responses of *Camptotheca acuminata* seedlings to different light environments," *Frontiers in Plant Science*, vol. 6, p. 321, 2015.

[55] Y. Xu, G. Wang, F. Cao, C. Zhu, G. Wang, and Y. A. El-Kassaby, "Light intensity affects the growth and flavonol biosynthesis of ginkgo (*Ginkgo biloba* L.)," *New Forests*, vol. 45, no. 6, pp. 765–776, 2014.

[56] M. Yuan, X. Jia, C. Ding, H. Zeng, L. Du, and S. Yuan, "Effect of fluorescence light on phenolic compounds and antioxidant activities of soybeans (*Glycine max* L. Merrill) during germination," *Food Science and Biotechnology*, vol. 24, pp. 1859–1865, 2015.

[57] L. Zoratti, K. Karppinen, A. L. Escobar, H. Haggman, and L. Jaakola, "Light-controlled flavonoid biosynthesis in fruits," *Frontiers of Plant Science*, vol. 5, p. 534, 2014.

[58] R. Ebrahimi, M. Souri, F. Ebrahimi, and M. Ahmadizadeh, "Growth and Yield of Strawberries under Different Potassium Concentrations of Hydroponic System in Three Substrates," *World Applied Sciences Journal*, vol. 16, no. 10, 2012.

[59] P. Sun, N. Mantri, H. Lou et al., "Effects of elevated CO2 and temperature on yield and fruit quality of strawberry (fragaria × ananassa Duch.) at two levels of nitrogen application," *PLoS One*, vol. 7, no. 7, Article ID e41000, 2012.

[60] A. M. Panico, F. Garufi, S. Nitto et al., "Antioxidant activity and phenolic content of strawberry genotypes fromFragariaxananassa," *Pharmaceutical Biology*, vol. 47, no. 3, pp. 203–208, 2009.