Effect of Different Doses of NPK at Different Time Intervals on Growth, Yield and Quality of Strawberry CV. Chandler (*Fragaria ananassa*)

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Abstract

Proper nutrition at the appropriate developmental stage is essential for the growth, yield and fruit quality of strawberries. Therefore, a study was carried out to check the effect of different doses of macronutrients at various, stages of strawberry cv. "Chandler". The strawberry runner was planted in a 10-inch plastic bag. NPK doses of 1g and 2g were applied at different physiological i.e., at planting, two to three leaves stage, and at blooming. Among all the treatments application of NPK @ 2 g increased all the vegetative as well as reproductive parameters including plant height (cm), number of leaves /plant, plant canopy measurement (cm), leaf area (cm3), leaf fresh weight (g), leaf dry weight (g), number of trusses per plant, number of flowers per plant, fruit set percentage, fruit weight (g), fruit size (cm), number of fruit set, total soluble solid (0Brix), vitamin c (mg/100ml) and titratable acidity (%). Application of these macronutrients @ of 1g also increased all these parameters significantly with respect to control. Comparison of treatment means showed significantly better results for vegetative parameters with different doses of NPK at the 2 to 3 leaves stage. The study also revealed that the application of NPK fertilizer at the flowering stage improved reproductive, as well as fruit quality parameters especially fruit size, weight, TSS, and ascorbic acid. It can be concluded that both reproductive and vegetative parameters were improved significantly when plants were treated with 2g NPK at the 2 to 3 leaves stage.

Key words: *NPK; Application; Chandler; Fertilizer; Treatment; Deficiency; Plant; Physiology.*

INTRODUCTION

Strawberry (Fragaria ananassa) is a perennial herbaceous plant belongs to Rosaceae family which is thought to be originated in France and North America (Memon, 2014). It is one of the world's most delicious and refreshing fruits which has achieved a leading role in the world fruit market as fresh and processed fruit (Wani et al., 2013). It has long been considered to have significant health advantages, owing to its high content of useful phytochemicals and essential nutrients, which seem to have relevant biological activity in human health (Scalzoet al., 2005). It is an emerging, subtropical and temperate fruit crop of the world. It was introduced in Pakistan during the early 1980s in Khyber Pakhtunkhwa (Rajwanaet al., 2016). Initially strawberry was grown in temperate zones of Pakistan, however now it is gaining popularity in tropical and subtropical areas of the country as well (Umar et al., 2009).National agriculture research council of Pakistan started working on strawberry cultivation in 1986. In Pakistan, with an annual production of 767 tons, strawberry is cultivated over an area of 227 hectares (GOP, 2017).

Strawberry has rapid growth (two to three months) and is extremely affected by environmental conditions such as temperature, light, salinity, water quality and nutrient availability. Because of its speed of development, the crop needs adequate macronutrient absorption to meet photosynthetic demand and fruit growth. The need for photosynthesis and rapid growth of strawberry plants is reported to require a high acquisition of macronutrients. Knowledge of crop nutritional requirement is important in developing profitable crop with better quality (Li et al.,2010). In plant growth and development, nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients. Playing a particular role in various physiological and morphological aspects as essential molecules associated with various fundamental metabolic processes (Takehisaet al., 2013).Nitrogen (N) is known as the most limiting nutrient to plant growth and development and its availability determines crop yield and quality. Phosphorus is an important nutrient and plays an important role in reproduction, vigor and general health of all plants. It is often referred as an energy source because during the photosynthesis it helps to store and transfer energy in plants Gastal & Lemaire (2002). Potassium increases crop yield and improves quality. It is required for numerous plant growth processes such as enzyme activation and stomatal activity Prajapati and Modi (2012).

Fertilizers are essential factors in determining the yield, quality and nutritional content of horticultural crops. For most of horticultural crops, researchers have helped to elucidate optimal NPK applications and other micronutrients. These studies have tended to concentrate mostly on crop yield (Stefanelli, 2010). Since efficient use of fertilizers plays a major role in crop production and yield. Furthermore high fertility levels not only put a heavy financial burden to the basic system of production, but also heavy use of chemical fertilizers as a source of nutrients show less fertilizer use efficiency (Pandey, 2017). Only limited amount of food elements can be absorbed from chemical fertilizers by the plants. The acidic and alkaline elements of the remaining chemical fertilizers react with soil which disturbs pH and makes the land infertile. Many of these fertilizers are acidic or basic in nature, hence long-term use of these fertilizers disturbs the pH of the soil which reduces the beneficial soil organisms thus degrades ecosystem and accelerate the process of soil erosion, and limit the availability of nutrients. Furthermore, K and P are costly nutrients and being used in huge quantity (Kumari et al., 2017). There is very limited literature available on the effect of NPK at different growth stages of strawberry plant and fruit quality. So, the present study was under taken to optimize NPK fertilizers and to evaluate the effect of macronutrients application on various growth stages for higher yield and better quality of strawberry CV “chandler”.

Materials and Methods

The present experiment was performed at university the research field of Pir-Mehr Ali-Shah Arid Agriculture University Rawalpindi (PMAS-AAUR) in 2018. The experimental site is situated between Latitude: 33.62 and Longitude: 73.07. Strawberry runners from SWAT were collected for plantation in 2018. Ten-inch clay pots were used to plant strawberry runners. Media composition was 1:1:1 with soil, sand and farmyard manure. In the center of the pots, plants were carefully planted and all pots were kept in lath house. Basic agricultural practices like weeding and irrigation were done uniformly for all plants.

The NPK doses of 1g and 2g were applied at three different physiological stages i.e., transplanting stage, two to three leaves stage and at blooming. Seven treatments were made including thirty strawberry plants in each, which were replicated thrice.

The research was based on completely randomized design. The collected observations were compiled and statistically analyzed using software STATISTIX 8.1 (ANOVA). The method of ANOVA was applied and variation among the treatments was undulated out using Least-Significant Difference (LSD) method of comparison at 5 percent probability level. (Steel, 1997).

Vegetative growth attributes: Vegetative parameters like plant height (cm) and plant canopy (cm) were measured with measuring scale and the data were recorded in centimeter. Other parameters like number of leaves and number of trusses were also recorded. The leaf area meter (Model LI-3100) was used for measuring leaf area, average values of 20 randomly selected leaves per treatment were recorded. Same number of leaves were also randomly selected for fresh weight and dry weight measurement and it was recorded in grams.

Reproductive growth parameter: For number of flowers randomly five plants per replication were selected average observations were noted on weekly basis to get average values. The fruit set percentage was determined by using following formula

$$\text{Fruit set percentage \%} = \frac{\text{Total number of fruit set}}{\text{Total number of flower}} \times 100$$

Fruit weight was determined with the help of weighing balance (Model SF-400C) of representative ten fruits from each replication. With the help of standard Vernier caliper fruit size was measured by taking average width and length of five selected fruit randomly from each treatment after harvesting. Data related mean fruit set was recorded by counting fruit numbers set on thirty plants. These pretreatment plants were selected per treatment per replication from 1st harvest to last harvest.

Fruit chemical characteristics: The total soluble solids were acid sugar proteins, total soluble salts and other substances found in the cell sap (Perez et al., 1997). For each treatment at room temperature, hand refractometer (Model SG-103)0was used to measure the TSS contents of harvested fruit. A drop of distilled water placed on refractometer to calibrate the reading and then strawberry juice drop was placed on the clean and dry prism of refractometer and readings were recorded in 0Brix (AOAC, 1990). Ascorbic acid contents of fruits for single treatment were measured by the method defined by (Hans, 1992), five grams strawberry pulp was taken and added 5 ml 0.1% hydrochloric acid and then put extract in centrifuge tube to centrifuge at 10,000 (RPM) for 10 min. The supernatant was collected as Ascorbic acid. The extract was measured0at 243 nm wavelength by spectrophotometer (OPTMA, SP-3000-Plus). To measure the extracted juice was shaken before the sample was taken and 10 milliliter of the juice extract was taken and added 40 milliliter distilled water to dilute solution. From diluted solution 10 milliliter of sample was taken in 100 milliliter in the flask and added three drops of phenolphthalein indicator. Taken 0.1 Normal NaOH in burette and added from burette drop by drop into flask to titrate the solution until light pink color was appeared (AOAC method no 943.15(1990).

At the maturation stage, acidity was measure by titration using the following formula:

$$\text{Titratable Acidity (\%)} = \frac{\text{N} \times \text{T} \times \ 0.0064}{\text{S} \ \times \text{D}} \times 100$$

Results

Vegetative growth attributes: Application of nutrients (NPK) significantly increased plant height of strawberry as compared to control. Highest plant height was observed when plants were treated with NPK @ 2g. 1g NPK treatment also increased plant height significantly as compared to control but these plants were significantly smaller than 2g NPK treated plants. Both 1g and 2g treatment of NPK showed highest result when these were applied during 2-3 leaves stage as compared to other two stages i.e., planting stage and blooming stage. The findings obtained by statistical analysis for the number of leaves varied significantly for strawberry crops when treated with different concentration of NPK at various stages of plant growth and development (Table 1). Significantly better number of leaves (13.79) of strawberry plant were recorded in treatment where 2 g of NPK were applied followed by one gram of NPK treatment while minimum number of leaves were observed in control (7.47). The mean data displayed that the maximum canopy spread (25.30 cm) was noted in plants which were treated with 2 grams of fertilizer, while the minimum canopy spread (15.14 cm) was exhibited by untreated plants. The mean (Table 1) indicate that the leaf area was significantly enhanced by use of NPK fertilizer. Maximum leaf area (54.65 cm) of strawberry plant was recorded where 2 grams of NPK fertilizer were applied followed by one gram of NPK fertilizer. While the minimum leaf area (38.52 cm) was noted in the plants which did not receive any treatment. The findings obtained by statistical analysis for the parameter of the leaf fresh and dry weight varied significantly for strawberry crop (Table 1). Meaningfully better leaf fresh and dry weight (1.89 g), (0.49 g) of strawberry plants were recorded in treatment where 2 grams of NPK were applied followed by 1 gram of NPK treatment while-minimum leaf-fresh and dry weight was seen in untreated plants (0.75 g), (0.17 g).

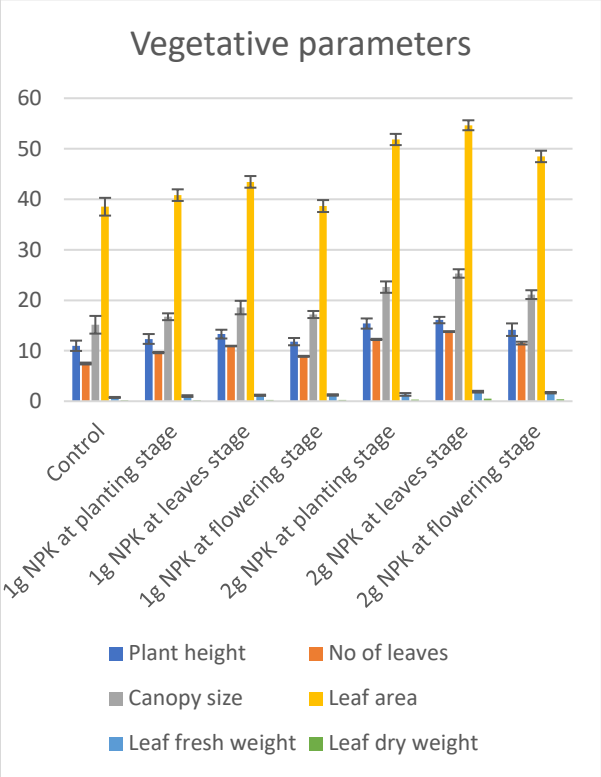
Table 1. Effect of different doses of NPK at different growth stages of strawberry vegetative attribute.

NPK	Stages	Plant height (cm)	No of leaves	Canopy size (cm)	Leaf area (cm^2)	Leaf F W (g)	Leaf D W (g)
0 g	Control	10.98±0.83 F	7.47±0.18 G	15.14±1.75 EF	38.52±1.75 D	0.75±0.05 D	0.17±0.06 GH
1g	Planting	12.33±0.98 D	9.63±0.12 E	16.73±0.68 CD	40.81±1.15 CD	1.02±0.07 C	0.21±0.03 F
1g	2-3 leaves	13.29±1.07 C	10.930.12± D	18.55±1.13 C	43.44±1.11 C	1.18±0.04 BC	0.28±0.04 D
1g	Blooming	11.80±0.99 DE	8.89±0.13 F	17.17±0.81 CD	38.65±1.05 D	1.24±0.04 B	0.24±0.04 E
Mean		12.47	9.82	17.48	40.97	1.14	0.24
2g	Planting	15.38±1.42 A	12.24±0.06 B	22.60±1.13 B	51.83±1.14 AB	1.35±0.05 B	0.35±0.04 C
2g	2-3 leaves	16.07±1.68 A	13.79±0.08 A	25.30±0.84 A	54.65±0.98 A	1.89±0.03 A	0.49±0.04 A

2g	Blooming	14.17±0.92 B	11.51±0.14 C	21.11±1.11 B	48.48±1.11 B	1.69±0.07 A	0.41±0.04 B
Mean		15.20	12.51	23	51.62	1.64	0.41
LSD		0.44	0.12	1.05	2.2	0.11	0.01

Means within a column having same letters are statistically non-significant using least significant difference Test and for the aforementioned parameters was Leaf Fresh weight and Leaf dry weight denoted by (Leaf F W) and (Leaf D W).

Figure 1. Effect of different doses of NPK at different growth stages of strawberry vegetative attribute.



Yield attributes

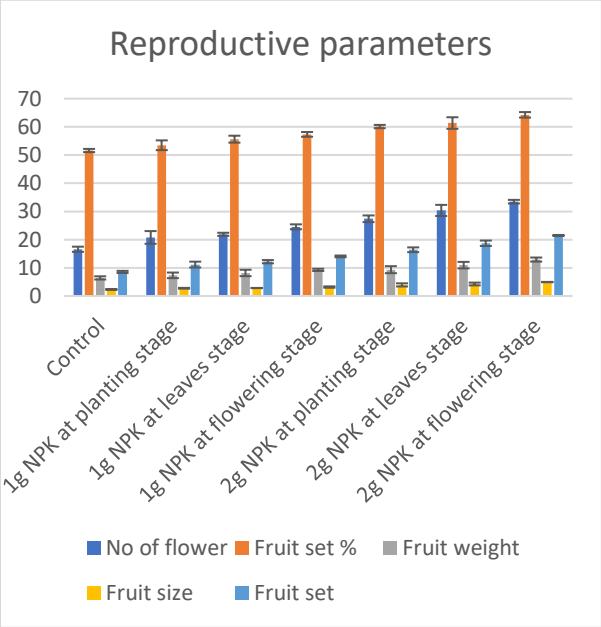
The data regarding number of flowers of strawberry is presented in Table 2. Analysis of variance (ANOVA) showed that Flower numbers were significantly improved when 2 grams of NPK fertilizer were applied at flowering stage. The maximum number of flowers (33.47) were noted when the plants were treated with 2 grams of NPK whereas the minimum number of flowers (16.58) were recorded at control treatment. Mean data and analysis of variance showed significant-difference between different concentrations of NPK fertilizer as mentioned in Table 2. The mean values showed that the fruit set percentage (64.27 %) was increased when treated with two grams of NPK fertilizer, while fruit set percentage (51.61 %) was reduced in untreated plants. The mean showed that the maximum fruit weight (12.93 g) was recorded in plants receiving 2 grams of NPK fertilizer, while the minimum value (6.42 g) was obtained in control. The data regarding fruit size of strawberry is presented in Table 2. Analysis of variance showed that the treatments and different stages of fertilizer displayed significant difference among different treatments concerning fruit size. The mean value showed fruit size was higher on NPK fertilizer at concentration of 2 grams which showed value (4.95 cm), while control exhibited least value for this parameter (2.32 cm). At different stages of NPK fertilizer showed maximum fruit size on flowering stage while minimum value was obtained at planting stage. Mean data and (ANOVA) regarding fruits set is given in Table 2. The data showed that fruit set was significantly influenced by NPK fertilizer concentrations, stages and interaction of both. It is revealed that the higher fruits were set by the treatment of NPK fertilizer at 2 grams (21.48), while the lowest fruits set were appeared at control (8.55).

Table 2. Effect of different doses of NPK at different growth stages of strawberry reproductive attribute.

NPK	Stages	No of flower	Fruit set %	Fruit weight	Fruit size	Fruit set
0 g	Control	16.58±0.92 F	51.61±0.57 E	6.42±0.57 D	2.32±0.11E	8.55±0.37 F
1g	Planting	20.78±2.25 E	53.48±1.72 D	7.33±0.98 CD	2.75±0.14DE	11.15±1.03 E
1g	2-3 leaves	21.88±1.18 DE	55.64±0.58 C	8.18±1.23 CD	2.83±0.55 DE	12.18±0.84 DE
1g	Blooming	24.55±1.27 CD	57.34±0.83 C	9.27±0.55 BC	3.18±0.31 CD	14.05±0.52 D
Mean		22.40	55.60	8.26	2.92	12.46
2g	Planting	27.40±0.55 BC	60.12±1.23 B	9.34±1.13 BC	3.94±0.03 BC	16.41±0.58 C
2g	2-3 leaves	30.36±1.97 AB	61.36±2.05 B	10.95±1.15 AB	4.26±0.49 AB	18.71±0.95 B
2g	Blooming	33.47±0.38 A	64.27±0.83 A	12.93±2.85 A	4.95±0.11 A	21.48±0.03 A
Mean		30.41	61.91	11.07	4.38	18.87
LSD		1.9	0.99	1.27	0.48	1.08

Means within a column having same letters are statistically non-significant using least significant difference Test.

Figure 2. Effect of different doses of NPK at different growth stages of strawberry reproductive attribute



Chemical characteristics of fruit

Application of nutrients significantly increased total soluble solid (TSS) concentration of fruit as compared to control. The mean data pertaining to TSS is shown in Table 3 revealed that total soluble solid improved with increasing level of NPK fertilizer. Maximum total soluble solid (6.8 0Brix) was recorded with 2 g NPK fertilizer followed by one gram of NPK treatment. Whereas least total soluble solid value (4.7 0Brix) was recorded in control. Different doses of NPK showed highest result when these were applied during blooming as compared to other stages. Non-significant differences were observed between the treatments of 2 g NPK at blooming and 2-3 leaves stage. The statistically analyzed data regarding vitamin C (ascorbic acid) is given in Table 3. Maximum vitamin C was recorded

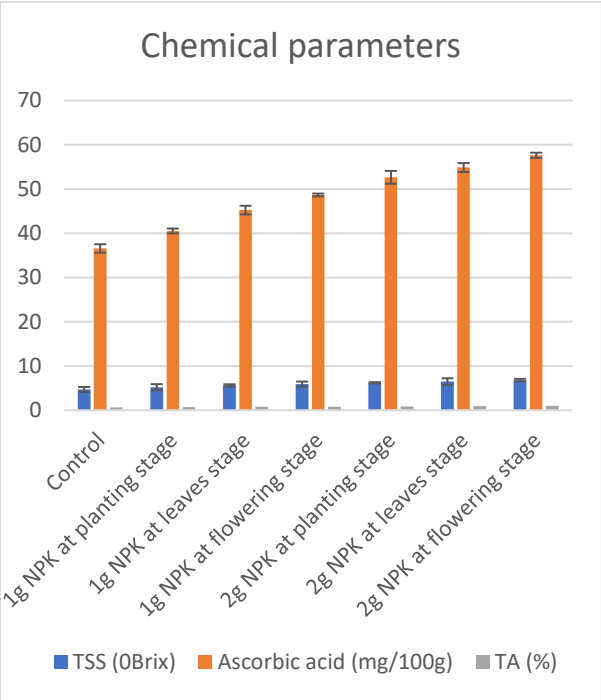
where 2 g of NPK fertilizers were applied followed by 1 g NPK fertilizer. While minimum vitamin C was noted in controlled treatment. Highest value of vitamin C, (57.63 mg/100g) was recorded when plants were treated with 2 g NPK fertilizer at flowering stage followed by 2 g NPK applied at leaves stage. While least value of vitamin C (36.57 mg/100g) was recorded in untreated plants. The statistically analyzed data indicated that different growth stages produced a nonsignificant impact on titratable acidity. Interaction between NPK and different stages of fertilizer showed that the titratable acidity was decrease due to 0.65 % when 2 grams of NPK fertilizer applied before flowering stage, while increase (0.97 %) was observed in control.

Table 3. Effect of different doses of NPK at different growth stages of strawberry chemical characteristic.

NPK	Stages	TSS (^{0}Brix)	Ascorbic acid (mg/100g)	TA (%)
0 g	Control	4.70±0.54 EF	36.57±0.95 GH	0.97±0.06 A
1g	Planting	5.20±0.69 DE	40.52±0.54 F	0.92±0.09 AB
1g	2-3 leaves	5.60±0.14 CD	45.24±1.44 E	0.87±0.14 AB
1g	Blooming	5.90±0.43 C	48.66±0.48 D	0.82±0.14 BC
Mean		5.56 B	44.80 B	0.87 A
2g	Planting	6.19±0.26 BC	52.65±0.98 C	0.78±0.24 BCD
2g	2-3 leaves	6.50±0.72 AB	54.86±1 B	0.72±0.14 CD
2g	Blooming	6.80±0.37 A	57.63±1.27 A	0.65±0.14 D
Mean		6.49 A	55.04 A	0.71 B
LSD		0.34	0.66	0.08

Means within a column having same letters are statistically non-significant using least significant difference Test and Titratable acidity was denoted by (TA) in percent.

Figure 3. Effect of different doses of NPK at different growth stages of strawberry chemical characteristic.



DISCUSSION

Strawberry plants respond to soil fertility like all other plants especially for NPK availability. Hence, low availability of these nutrient in the soil is the reason of stunted growth as observed in present experiment under controlled condition. Strawberry plants under control had lowest values of vegetative and reproductive growth. These consequences were in line with our expectations of better growth with NPK fertilizer application. The unavailability of nutrient (NPK) in the soil (without their exogenous application) proved by good results in strawberry even under 1 g NPK per plant. Higher growth values displayed by strawberry under 2 g NPK per plant treatment as compared to 1 g both at vegetative and reproductive stage presented that application of 1 g NPK fertilizer was inadequate for their growth.

Application of 2 g NPK fertilizer seems to supply sufficient nutrient for strawberry plant especially at vegetative as well as reproductive growth stages. Vegetative attributes increased as a result of 2 g NPK fertilizer applied during 2-3 leaves stage. Similarly, almost all reproductive parameters increased when 2 g NPK was applied during flowering stage. Results reflect an improvement in vegetative growth parameters in response to fertilizer application in higher dozes. Similar results were observed by (Alonge et al., 2007) when NPK was specifically applied during vegetative stage. Improvement of vegetative growth parameters like height of plant, diameter of stem and number of leaves with increase in nitrogen fertilizer rate can be attributed to increased uptake of nitrogen and it plays critical role in chlorophyll synthesis Aslani et al (2018). Therefore, the process of photosynthesis and carbon dioxide (CO2) assimilation leading to improve growth characteristics. Number of leaves per plant shows highest result when plants were treated with 2 g NPK fertilizer specifically during 2-3 leaves stage. As treatment of 2 g NPK during planting time and flowering stage showed higher results as compared to control but are lower than treatment of 2 g NPK at 2-3 leaves stage.

In the present study higher doses of NPK fertilizer at leaves stage application increased the canopy of strawberry because at vegetative growth plants need more nutrients for their growth and development. Enhancing effect of NPK on plant growth might be attributed to their vital contribution in several metabolic processes in plants, related to growth and also their role in assimilating the photosynthetic reactions. Similar result was also obtained by (Urban, 2021). Increase in plant vegetative parameters as a result of application of NPK

might be due to synthesis of proteins and carbohydrates in different plants. Similarly, phosphorus also has critical role in plant growth and development as well as in energy transformation in the form of phosphate group. Increase in plant height and number of leaves in NPK treated strawberry plants were also because of regulatory role of potassium in carbohydrate metabolism and increasing the water utilization efficiency. Our results are in close conformity with the findings of (Singh et al., 2006).

The improvement of vegetative growth parameters like height of plant, diameter of stem and leaves number with increase in nitrogen fertilizer rate can be attributed to increase in uptake of nitrogen and it plays critical role in chlorophyll synthesis. Therefore, the process of photosynthesis and carbon dioxide (CO2) assimilation leads to improve growth characteristic. The available nutrients including nitrogen, phosphorus and potassium to the plants indirectly increased the vegetative parameters including number of leafs, plant growth, leaf area and canopy which was due to the consequence that these nutrients as a part of diverse proteins and enzymes, boost up metabolic process in plant cell and hence increase plant growth attributes (Maurya et al., 2017).

Results also indicate that leaf area was significantly enhanced by use of NPK fertilizer. The growth parameters such as leaf area was increased significantly with the availability of nitrogen. Plant metabolic rate as well as chlorophyll synthesis increased which ultimately enhanced plant growth aspects (Singh et al., 2008).

Availability of nitrogen to the plants helped in utilization of carbohydrates and proteins. Phosphorus helped in root development and early maturity through recovery of reactions. On the other hand, many fundamental reactions including carbohydrate metabolism and enzyme activation in plant medium were also found to support by potassium (Bahadur et al., 2004).

Increase in yield characteristics might be due to proper utilization of carbohydrates, proteins and gathering of photosynthetic as well as many other functions including carbohydrate metabolism, enzyme activation, translocation of sugars and starch by the supply of optimum level of NPK. These findings were also confirmed in earlier researcher Supe and Marbhal (2008). The reproductive parameters i-e fruit size and fruit weight were increased when nutrients were applied during flowering stage. The reason behind improvement of plants required more nutrients because higher metabolic process rate due to availability of nutrients for plants that led to increase in overall performance of reproductive yields. The similar result was obtained by (Ahmad et al., 2005).

Number of flowers and fruit set percentage are key parameters for determining yield. In current study NPK application significantly increased these parameters. As higher numbers of fruits per plant and their successful pollination could be attributed to more flowers per plant and fertilization while fruit weight seems to be attributed to fruit length and diameter because of proper plant nutrition under optimum application of balanced N, P and K nutrient fertilizer (Ristow et al., 2018). Similar study Al-Imam and Alsaidi (2007) showed that NPK fertilization caused significant increase in berry setting percentage in grapes.

Overall performance of plants including metabolic processes was increased and hence

plant reproductive as well as vegetative growth also improved. Higher number of flowers per plant and their successful pollination could be attributed to more flowers per plant and fertilization, while fruit weight seemed to be attributed to fruit length and diameter because of proper plant nutrition under optimum application of N, P and K nutrients. In case of strawberry 2g NPK per plant found to be more effective for sustainable yield and quality characteristics.

Current study shows that application of NPK fertilizer on strawberry plants shows significant improvement in fruit quality characteristics including total soluble solids and vitamin C content. Nitrogen fertilizers mostly help in the vegetative growth of plants as a result plant vigor in terms of number of leaves, leaf area and plant canopy increased. Improvement in vegetative characteristics increased photosynthetic area, ultimately increasing the rate of photosynthesis and more carbohydrates are formed which are further utilized by plant in fruit development. These improvements in plant metabolism increase the rate of translocation of foods from source (leaves) to sink (fruits). Similar results were obtained in strawberry plant by (Umar et al.,2009).

Our study shows that application of NPK fertilizers to strawberry plant decreased the acidity (titratable acidity) because availability of these nutrient to the plants increases conversion of organic acids in to sugars. Hence fruit quality attributes were improved in these plants with respect to control. These outcomes are in line with the findings of (Gutal et al.,2005). Fertilizer application i.e., NPK positively regulate almost all functions. These improvements in plant performance further increase ascorbic acid content of strawberry. Treatment of NPK nutrients improved synthetic and catalytic activities of several enzymes and co-enzymes that are directly or indirectly involved in ascorbic acid synthesis. These results are also confirmed by Boora and Singh (2000).

Conclusion:

The finding has shown that strawberry plant responds to soil fertility like all the other plant especially for NPK availability under various treatments. The application of 2g NPK fertilizer at leaves stage significantly higher than that of 1g NPK fertilizer at leaves stage and improve vegetative growth attribute of strawberry plants while application of 2g NPK fertilizer at flowering stage significantly higher than that of 1g NPK at flowering stage hence improve yield attribute.

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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

CONSENT OF PUBLICATION: Not applicable

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