The present research work entitled “Effect of Inorganic and Bio-fertilizers on growth, Yield and Physico-chemical Characters of Strawberry (Fragaria x annanasa L. Duch.) cv. Chandler in Central Uttar Pradesh” was carried out at the Horticulture Research Farm-I, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Rae Bareli Road, Lucknow (U.P.) during 2014-2015 and 2015-2016. The results are discussed in the light of literature available and research works reported by earlier workers on strawberry and other related fruit plants relevant and logical explanation have been given wherever possible.

5.1. Effect of Inorganic and Bio-fertilizers on growth parameters:

The vegetative growth characters of strawberry cv. Chandler in terms of plant height, plant spread, number of leaves per plant, leaf length, leaf width and number of runners per plant, are presented in Table 4.1 and 4.2 for two consecutive years (2014-15 and 2015-16) of experimentation.

From the observations made during both years, it was finding that the combination of 100 Kg N ha⁻¹ + Azotobacter was able to produce the tallest plants. This might be due to the higher dose of Nitrogen along with the Azotobacter. It has been reported that such enhancement of plant growth may be attributed to the existence of biologically plant growth promoting mechanisms. Nitrogen is responsible for increased plant growth, essential components of proteins, protoplasm and chlorophyll. Similar findings are also reported by Ahlawat et al., (1988), Andersson et al., (2012), Tripathi et al., (2010) in strawberry, whereas production of growth regulators by the Azotobacter in the root zone which gets absorbed by the plant roots has been reported by Rana and Chandel (2003) in strawberry. The use of bio-fertilizer is increasing day by day due to increase in the price of chemical fertilizers, its beneficial effect on soil health and increase in production of crop Hazarika and Ansari (2007). Organic products are being famous for all people around the world.
Due to the great global market demand, production of organic foods has rapidly increased in the past decades. On this basis organic agriculture has become a great choice as means of organic product producing. Organic cultured strawberries produced higher vegetative growth in compare to conventionally cultured strawberries produced Abu-Zahra and Tahboub (2008).

The maximum plant height was recorded in both years with treatment $T_2$ due to the application of full dose Nitrogen with combination of Azotobacter i.e. 100 Kg N ha$^{-1}$ + Azotobacter, because nitrogen play a vital role for plant vegetative growth and the nitrogen availability also enhances by the use of Azotobacter which accumulate the environmental nitrogen easily to the plant. Nitrogen also helps to constitution of cell wall, impart green colour to plant, encourage vegetative growth, essential constitution of protein, play important role of synthesis of auxin. The application of Vermicompost + Azotobacter + PSB + AM produced maximum plant height (20.26 cm) Anil et al. (2015). Among the fertilizers, the single effect of N (115 kg ha$^{-1}$), P (40 kg ha$^{-1}$), K (110 kg ha$^{-1}$) and S (25 kg ha$^{-1}$) gave maximum growth and yield of strawberry. The highest concentration of N, P, K and S were found in shoot and fruit of strawberry when N, P, K and S fertilizers were used 140, 60, 135 and 35 kg ha$^{-1}$, respectively. The highest values of plant height (25.60 cm) Afroz et al. (2016). Gupta and Tripathi (2012) examined that the combined application of Azotobacter 6 kg per ha and Vermicompost 30 tonnes per ha significantly increased the height of plant (19.45 cm).

In both years the spreading of plant was observed highest in $T_2$ 100 Kg N ha$^{-1}$ + Azotobacter followed by treatment $T_4$ 75 Kg N ha$^{-1}$ + Azotobacter, it may be due to the Azotobacter which enhance the growth of nitrogen fixing and phosphate solublizing micro-organisms enhance the phosphorus activity in plants. It may enhance the growth as well as the nutrient in the plant. The micro-organisms Azotobacter and Phosphate Solublizing Bacteria helps to increase the N and P availability by making available biologically fixed N and biologically solubilize P was attributed to the intimate mixing of ingested particles within soil. Similar results also find by Anil et al. (2015) application of Vermicompost + Azotobacter + PSB + AM produced maximum plant height (20.26 cm), plant spread (25.64 cm), number of leaves (54.30) and leaf area (97.87 cm$^2$) plant$^{-1}$, whereas all the growth characters
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were found minimum in control. **Dar et al. (2013)** the application of 100 kg N + 80 kg K/ha resulted in maximum growth and yield improvement in strawberry followed by 100 kg N treatment and 80 kg P + 80 kg K/ha treatment. The study revealed that strawberry crop requires optimum NPK to harness maximum yield.

The mean value shows the maximum leaf under the application of $T_2$ (100 Kg N ha$^{-1}$ + *Azotobacter*) followed by $T_4$ while, the lowest numbers of leaves were found in ($T_1$) control (No Inorganic and no Bio-fertilizers). The application of *Azotobacter*, urea with addition to the higher concentration of *Azotobacter* might have helped in N-fixation and its quick release for plants absorption. Increase in the number of leaves might be due to the production of more chlorophyll content with inoculation of nitrogen fixers. The other reason for increased vegetative growth may be due to the production of plant growth regulators by *Azotobacter* in the rhizosphere which are absorbed by the roots. Better development of root system and the possibly synthesis of plant growth hormones like IAA, GA3 and cytokinin and direct influence of *Azotobacter* might have caused increased number of leaves per plant. These results are suggested by **Jeeva et al. (1988)** reported that the application of *Azospirillum* inoculation in banana with graded levels of N fertilizers (100, 75, 50 Kg) of the standard rates was investigated. Inoculation + highest dose of N (100%) enhanced the height and girth of pseudostem, number of leaf and leaf area. **Kumar et al. (2014)** claimed the maximum plant height, maximum number of leaves, spread of plant, number of flowers, length diameter ratio of fruits and average number of fruit per plant in strawberry was recorded with the application of 100 kg N/ ha. **Rana and Chandel (2003)** used bio-fertilizers and nitrogen to strawberry cv. Chandler and found that *Azotobacter* inoculated plants attained maximum plant height (24.92 cm), number of leaves (26.29), leaf area (96.12 cm$^2$), and number of runners (18.70) per plant as compared to other treatments. They further observed that the application of *Azotobacter* in combination with 60 kg N per ha produced maximum leaf area (102.50 cm$^2$) over all other treatments.

The maximum leaf length in both experimental years was found in treatment $T_2$ (100 Kg N ha$^{-1}$ + *Azotobacter*) followed by $T_3$ (100 Kg N ha$^{-1}$ + PSB) and $T_4$ (75 Kg N ha$^{-1}$ + *Azotobacter*) while, the minimum leaf length was observed under the control (No Inorganic and no Bio-fertilizers) treatment. The observation of leaf length
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similar by Jeeva et al. (1988) reported that the application of Azospirillum inoculation in banana with graded levels of N fertilizers (100, 75, 50 Kg) of the standard rates was investigated. Inoculation + highest dose of N (100%) enhanced the height and girth of pseudostem, number of leaf and leaf area. Rube et al. (2013) observed that the maximum height of the plant, number of leaves per plant, length of leaves and width of leaves were recorded in the treatment T$_{12}$ - Azotobacter (50%) + Azospirillum (50%) + NPK (50%) + FYM.

The minimum mean leaf length was examined in treatment T$_1$ i.e. control which shows the value width due to without application of any fertilizer dose. The maximum value also find out by the treatment T$_2$ (100 Kg N ha$^{-1}$ + Azotobacter) followed by T$_3$ (100 Kg N ha$^{-1}$ + PSB) and T$_4$ (75 Kg N ha$^{-1}$ + Azotobacter). The same result also reported by Kumar et al. (2014) claimed the maximum plant height, maximum number of leaves, spread of plant, number of flowers, length diameter ratio of fruits and average number of fruit per plant in strawberry was recorded with the application of 100 kg N/ ha. Umar et al. (2009) determined the positive effect of organics, FYM, in integration with urea and Azotobacter on strawberry cv. Chandler. They reported that maximum height of plant (21.24 cm), plant spread (28.16 cm), leaf area (74.9 cm$^2$) was in 100% N (Urea) + Azotobacter treated plants.

The pooled data clearly shows that the maximum number of runners were found in T$_2$ (100 Kg N ha$^{-1}$ + Azotobacter) followed by T$_3$ (100 Kg N ha$^{-1}$ + PSB), whereas the lowest number of runners were produced under the control plots. The increased runner production under higher concentration of Azotobacter treated plots might be due to secretion of growth promoting substances, especially cytokinin by Azotobacter which increases the runner production in strawberry. Similar findings were also reported by Rana and Chandel (2003), Sahoo and Singh (2005); Nazir et al. (2006) in strawberry. Increased number of runners per plant might be due to the increased growth of plant in the form of height, number of leaves and leaf area, which accumulated more photosynthates and thereby increased runners per plant. The results are in conformity with the findings of Lata et al. (2013), Sharma et al. (2004) and Umar et al. (2009) in strawberry, where they observed that the integrated nutrient management was better than the single application of nutrients for runner production in strawberry.
5.2. Effect of Inorganic and Bio-fertilizers on Yield parameters:

The yield parameters also influenced by the application of organic and inorganic fertilizers with different level of doses in both experimental periods.

The average value of both years clearly showed that the maximum number of fruits was found in treatment $T_{12}$ (10.83) followed by $T_{11}$ (9.99), $T_{13}$ (9.99) whereas, the minimum was observed in $T_1$. Similar finding was also observed by Gaur and Deepak (2003) carried out that application of 200 kg N/ha resulted in the maximum plant height (19.90 cm), maximum number of leaves per plant (23.15), maximum average number of flowers per plant (3.95), fruit set (68.35%), fruit length (2.56 cm), fruit width (2.04 cm), number of fruits per plant (16.7) and average fruit weight (7.90 g). Azotobacter is expected to hasten plant development; hence an increase in fruit set in the present studies is due to the cumulative effect of Azotobacter and fertilizer application. This increase in number of fruits per plant possibly due to the fact that Azotobacter and N, P, K application accelerated the development of inflorescence, leaf number in autumn, which are positively correlated with the number of fruits in the following spring. Increased number of fruit might have also resulted because of increase in number of crowns per plant. Similar observations were also reported by Kumar et al. (2014) claimed the maximum plant height, maximum number of leaves, spread of plant, number of flowers, length diameter ratio of fruits and average number of fruit per plant in strawberry was recorded with the application of 100 kg N/ha Pandit et al. (2015), Tripathi et al. (2010) in strawberry.

The pooled data as presented clearly revealed the significant differences among the treatments. The longest fruits were observed in $T_2$ 5.68cm (100 Kg N ha$^{-1}$ + Azotobacter) which were significantly higher to other treatments, whereas the shortest fruit was recorded in control (No Inorganic and no Bio-fertilizers). The same result was also assed by Afroz et al. (2016) the highest values of plant height (25.60 cm), number of leaves (21.66), flowers (125.33), fruits (12.35),destroyed fruits (11), fruit weight (215.10 g) plant$^{-1}$ and fruit length (4.16 cm). Gaur and Deepak (2003) carried out that application of 200 kg N/ha resulted in the maximum plant height (19.90 cm), maximum number of leaves per plant (23.15), maximum average number of flowers per plant (3.95), fruit set (68.35%), fruit length (2.56 cm). Kumar et al. (2014) claimed the maximum plant height, maximum number of leaves, spread of
plant, number of flowers, length diameter ratio of fruits and average number of fruit per plant in strawberry was recorded with the application of 100 kg N/ha.

During 2014-15 fruit width was ranged from 3.60cm to 4.47cm. With maximum fruit width was observed in $T_2$ (4.47cm) $100$ Kg N ha$^{-1} + \text{Azotobacter}$ followed by $T_4$ (4.42cm), $T_3$ (4.37cm). Minimum fruit width was observed in control (3.60cm). During 2015-16, fruit width varied from 3.93cm to 4.80cm. Maximum fruit width (4.80cm) was recorded in $T_2$ ($100$ Kg N ha$^{-1} + \text{Azotobacter}$) followed by $T_3$ (4.71cm), whereas minimum fruit width was observed in control (3.93cm). The similar findings also suggested by Rayees et al. (2015) the data regarding the different growth parameters observed at 30, 45, 60, 90, 105, 120 days after planting, yield parameters at 45, 60, 90, 120, 135, 150 days after planting and their quality parameters clearly indicate that the application of integrated sources of nutrients significantly affect the vegetative, reproductive and yield characteristics of the strawberry plant. Sara et al. (2015) in this regard, studies were conducted using six different organic amendments on strawberry ($\text{Fragaria ananassa}$ Duch.) cv. Chandler which included $T_1$ = planting media (soil + silt + farm yard manure); $T_2$ = planting media + 400 mgL$^{-1}$ humic acid; $T_3$ = planting media + 200 g kg$^{-1}$ leaf manure; $T_4$ = planting media + 200 g kg$^{-1}$ Vermicompost; $T_5$ = planting media + 200 g kg$^{-1}$ plant fertilizer and $T_6$ = planting media + 200 g kg-1 bio-compost during 2011-12 at PMAS-Arid Agriculture University, Rawalpindi. Treatment $T_1$ (soil + silt + FYM) induced positive influence on plant height (15.21 cm), canopy spread (20.37 cm), crown diameter (1.47 cm), fresh weight of plant (10.71 g), number of runners per plant (2), total number of flowers (58), total number of fruits (42), fruit size (3.04 cm).

The mean value of both years revealed that the maximum fruit weight was observed in $T_2$ followed by $T_5$ and $T_4$, respectively but minimum value asses in control (No Inorganic and no Bio-fertilizers). The values also examined by Tripathi et al. (2015) study the influence of Azotobacter, Vermicompost on growth, flowering, yield and quality of strawberry cv. Chandler. There were nine treatments comprising two levels each of Azotobacter (6 and 7 kg/ha) and Vermicompost (20 and 30 t/ha) and their combinations along with one control, replicated thrice in randomized block design. Five kg of FYM was applied as a basal dose in all the treatments including control. Plants fertilized with Azotobacter at 6 kg/ha + Vermicompost at 30 t/ha also
produced the berries with maximum length (4.76 cm), width (2.49 cm), weight (8.75 g). **Umar et al. (2010)** have reported that application of 25% nitrogen through subabul + 75% nitrogen in the form of urea augmented with bio fertilizer resulted in maximum plant height (20.9 cm), plant spread (27.8 cm) leaf area (70 cm²), fruit size(38.4 x 28.9mm), T.S.S (6.836 °Brix), Total sugar(4.85%), fruit weight(16.9 g).

Fruit yield per plant varied significantly affected by the various doses of fertilizer and Bio-fertilizers. The mean values of both years showed the maximum value of fruit yield per plant in treatment T₂ followed by T₃ and T₄, whereas the minimum yield per plant was observed under control (No Inorganic and no Bio-fertilizers). The result also observed by **El – Hamid et al. (2006)** observed that application of P.S.B. (5 Kg/ha) in strawberry resulted increased size, firmness and yield (252 g/plant). **Gupta and Tripathi (2012)** examined that the combined application of Azotobacter 6 kg per ha and Vermicompost 30 tonnes per ha significantly increased the yield (324.38 g/plant).