2.1 Vegetative growth


Wang et al. (1997-98) reported microbial inoculation of *Azotobacter* significantly increased the number of leaves per plant and number of buds per plant in strawberry.

Wang et al. (1998) inoculated strawberry cv. Australian, Sujata and Labella with bio-fertilizer or their combinations before planting. Result revealed that cv. Sujata performed better than other two cultivars with bio-fertilizer. Inoculation of bio-fertilizers significantly increased the number of leaves per plant and number of buds per plant. The most effective microbial combination tended to be the Microphos (PSB) *Azotobacter* and Azospirillum, *Azotobacter* + Azospirillum and *Azotobacter* + Azospirillum + PSB inoculation was also significant.

Chol et al. (2000) reported that nitrogen uptake increased the fresh weight and recommended 80-110 mg/liter of concentration of nitrogen to achieve highest crop growth in ‘Nyoho’ strawberry.

Naidu et al. (2001) evaluated the effect of different dose of organic manure viz. F.Y.M., vermicompost, pressmud and biofertilizers alone and with combination on tomato and showed that, number of nodes intermodal length, number of fruits, weight of fruits/plant were increased.

Arancon et al. (2003 and 2004) applied vermicompost in strawberries and observed the improvement in plant growth and fruit yield. They observed a partial to full scale increase in soil microbial biomass too, leading to the production of hormones and humors independently to the soil.

Rana and Chandel (2003) used biofertilizers and nitrogen for strawberry cv. ‘Chandler’ and found that *Azotobacter* inoculated plants attained maximum plant
height (24.92 cm), more number of leaves per plant (26.29), more leaf area (96.12 cm²) and more number of runners per plant (18.70) as compared to other treatments. They further observed that the application of *Azotobacter* in combination with 60 kg N/ha produced maximum leaf area (102.50 cm²) over all other treatments.

Arancon *et al.* (2004) reported that application of vermicompost of (10 tones/ha) in strawberry cv. Chandler was recorded increase in the leaf area (37%), flowers (36%) and numbers of plant runner (25%).

Sahoo and Singh (2005) reported that the application of Azotobacter (6 kg per ha⁻¹) and Azospirillum (5 kg per ha⁻¹) in strawberry cv. Sweet Charlie during Rabi season resulted that the maximum number of leaves, plant height and number of branches per plant.

Nazir *et al.* (2006) conducted a field experiment to study the effect of various organic nutrient combinations on the yield and growth of strawberry cv. Senga Sengana. The treatment comprised five nutrient organic treatment combinations including the recommended dose of N, P and K through chemical fertilizers and a control. Poultry manure + *Azotobacter* + wood ash + PSB + oil cake recorded the maximum values for plant height (23.39 cm), plant spread (24.21 cm) and runners per plant (13.03).

Poniker *et al.* (2006) reported that in turmeric application of NPK + *Azotobacter* + PSB (each at 250 g/kg seed) + FYM (10 t/ha) resulted in maximum plant height, number of leaves, size and surface area of leaves and number of tillers per plant with highest C:B ratio.

Nowsheen *et al.* (2006) found that the application of P.S.B. on strawberry cv. Chandler resulted the highest plant height (24.45 cm), plant spread (23.96 cm), increased runners per plant (14.1) and maximum number of leaves.

Baksh *et al.* (2008) applied 100% NPK + 250 g PSB + 250 g *Azotobacter* per tree in two split doses i.e. in February for Ambe bahar and in June for Mrigbahar in guava flowering. They found the maximum increase in growth parameter i.e. plant height, plant spread and trunk girth with this treatment during both season.
Bhadure et al. (2008) reported that the application of Azotobacter chroococcum bio-fertilizer resulted in tallest plant and maximum number of branches per plant among seven treatments in brinjal.

Iqbal et al. (2009) noticed that plants height of 21.24 cm with 28.16 cm plant spread, 74.95 cm² leaf area, 37.62 × 28.01mm fruit size and 15.87 g fruit weight with the application of 25 per cent nitrogen through FYM augmented with Azotobacter and was at par with the plants supplied with cent per cent nitrogen in the form of urea in combination with Azotobacter in strawberry cv. Chandler.

Sekhar and Rajashree (2009) reported that FYM 20 t/ha recorded the highest number of fruits per plant and fruit weight in cowpea. The total soluble solids content of fruits was also increased with application of FYM when compared to control.

Umar et al. (2009) determined the positive effect of FYM in integration with urea and Azotobacter on strawberry cv. Chandler. They reported that the maximum height of the plant (21.24 cm), plant spread (28.16 cm), leaf area (74.9 cm²) was in 100% N (Urea) + Azotobacter treated plants.

Yadav et al. (2009) concluded from their work that the majority of growth parameters of strawberry like number of crowns, number of runners, length of runners, number of plantlets and fruit characteristics like number of flowers, number of berries, fruit yield and net monetary return were recorded maximum in Azotobacter inoculated treatments with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer.

Yadav et al. (2010) reported that the Azotobacter inoculated treatments significantly increased in growth and yield parameters viz. plant height (16.65 cm), spread (34.52 cm), and leaf area (108.32 cm²).

Singh et al. (2010) revealed that with the increase in dose of vermicompost, there was increasing trend for plant growth, yield and quality parameters of strawberry.

Tripathi et al. (2010) applied 5, 6 and 7 kg each of Azotobacter, Azospirillum and PSB in strawberry cv. Chandler and reported that the soil application of 7 kg per
ha. *Azotobacter*, significantly increased the plant height (16.05 cm) number of leaves (54.75), number of crowns (6.34) and runners (4.39).

Patil and Shinde (2013) reported that the vegetative growth parameters maximum were recorded in treatment 50% RDF+ FYM+ *Azotobacter* (50g/plant)+ PSB(50g/plant)+ VAM (250g/plant) which are plant height, plant girth, number of leaves per plant, leaf area in crop duration.

Verma and Rao (2013) reported that the maximum vegetative growth parameters in banana were recorded in treatment 50% RDF+PSB+ Vermicompost+ *Azotobacter* which are plant height (22.08 cm), plant spread (37.06 cm), leaf area (112.84 cm²) in strawberry cv. Chandler.

### 2.2 Flowering and Yield

Wang (1996) reported that inoculation of *Azotobacter* in strawberry cv. Sujata increased number of leaves, buds, flowers and fruits per plant they further reported that inoculation of P.S.B. on strawberry cv. Australian Labella increased height of plant, number of leaves, number of flowers, leaves and buds per plant.

Wang *et al.* (1997-98) worked on various biofertilizers inoculants containing *Azotobacter*, PSB, Azospirillum and reported a significant increase in number of fruit per plant, total weight and average weight of berry compare to control in strawberry.

Wang *et al.* (1998) inoculated strawberry cv. Australian, Sujata and Labella with bio-fertilizer or their combinations before planting. Result revealed that cv. Sujata performed better than other two cultivars with bio-fertilizers. Inoculation of biofertilizers significantly increased the number of fruits per plant total weight of fruits and average weight of fruits as compared to uninoculated plants. The most effective microbial combination tended to be the Microphos PSB, *Azotobacter* and Azospirillum, *Azotobacter* + Azospirillum and *Azotobacter* + Azospirillum + PSB inoculation was also significant.

Cheziyan *et al.* (1999) reported that the effect of F.Y.M. (40 tones/ha) recorded highest plant height, number of leaves and number of flowers per plant in banana.
Sahoo and Singh (2005) conducted a field experiment to evaluate the effect of soil application of different levels of bio-fertilizers such as *Azotobacter* and Azospirillum on the growth, yield and quality of strawberry cv. Sweet Charley and found the different levels of bio-fertilizers exhibited significant effect on growth yield and quality attributes. The treatment with *Azotobacter* resulted in the maximum value of attributes.

Turemis (2002) studied the effect of different organic deposits (wheat straw, corn, tobacco and banana Arial stem, farmyard manure, poultry manure and combination of these materials) on yield and quality of strawberry cv. Dorit – 216 and reported that all the composts accelerated bloom date compared to control. He pointed out that composts continued to decompose after application resulting in increased temperature in the rhizosphere. These higher temperatures may be responsible for the acceleration of bloom.

Arancon *et al.* (2003) observed that application of vermicompost (20 tones/ha) strawberry (*Fragaria sp.*) recorded increased leaf area, number of suckers, number of flowers and shoot length per plant.

Rana and Chandel (2003) recorded the maximum yield (73.60 q/ha) of strawberry cv. Chandler with the application of *Azotobacter*. Maximum weight of berries was also recorded in *Azotobacter* inoculated plants.

Arancon *et al.* (2004) reported that application of vermicompost (10 tones/ha) in strawberry cv. Chandler resulted maximum number of flowers 40% per plant.

Nowsheen *et al.* (2006) found that the application of P.S.B. in strawberry cv. Chandler resulted the highest plant height, plant spread maximum number of flower and runners per plant.

Tripathi and Babu (2008) reported that application of *Azotobacter* at 6 kg/ha significantly increased the height of plant, number of leaves, crowns, runners, number of flowers and fruit set per plant. They also found that maximum duration of harvesting and minimum number of days taken to produce first flower with
significantly maximum yield of quality berries were also produced in *Azotobacter* at 6 kg/ha fertilized plants.

Singh and Singh (2009) conducted an experiment to study the effects of bio-fertilizers (*Azotobacter* and *Azospirillum*) and bio-regulators in strawberry cv. Sweet Charlie. They reported that dual inoculation of *Azotobacter* and *Azospirillum*, in combination with 60 kg nitrogen/ha and 100 ppm GA$_3$ was the most effective treatment in increasing fruit set, early flowering, yield and fruit quality (i.e. berry size, weight ad volume). The maximum total soluble solids (TSS), total sugar and ascorbic acid content were obtained with the same treatment combination, however, the effect on acidity and TSS/acid ratio was found to be non-significant.

Umar *et al.* (2009) recorded the maximum yield of strawberry cv. Chandler fruits per plant with the inoculation of *Azotobacter* + 100% (Urea).

Tripathi *et al.* (2010) applied 5, 6 and 7 kg each of *Azotobacter*, *Azospirillum* and PSB in strawberry cv. Chandler and reported that the soil application of 7 kg per ha. *Azotobacter*, significantly increased the number of flowers (52.38) and fruits set (25.66) per plant. Maximum duration of harvesting (67.10 days ) and minimum number of days (62.26 days) taken to produce first flower with significantly more yield (180.89 g/plant) were also observed in *Azotobacter* at 7 kg/ha fertilized plants.

Yadav *et al.* (2010) reported that inoculation of 2 kg/ha Azotobacter with 50% N by VC + 50% N by CF resulted in maximum number of flower and number of fruit set per plant in strawberry cv. Chandler.

### 2.3 Yield attributes

Lucka *et al.* (1975) reported that application of F.Y.M. and compost mixture (1:1) 500 q/ha on strawberry cv. Purpuratka resulted the highest total yields (170 t/ha$^{-1}$).

Rudenko (1984) observed that application of F.Y.M. (10 tones/ha) on strawberry obtained maximum yield.

Arancon *et al.* (2003 and 2004) used food waste and recycled paper vermicompost @ 5 t/ha and 10 t/ha and compared with inorganic control plots which
received recommended rate of fertilizers. All the vermicomposted plots were supplemented with amount of inorganic fertilizers to equalize the initial nitrogen level available to the plants in all the time of transplanting. They reported that application of vermicompost significantly increased number of flowers and total number of marketable berries. Total marketable strawberry yield increased (35%) significantly in plots treated with vermicompost compared to those that received inorganic fertilizers only.

Rana et al. (2003) reported that application of Azotobacter on strawberry cv. Chandler produced maximum yield (73.12 q/ha) fruit length (35.94 mm), fruit width (22.91 mm), fruit weight (9.11 g).

Tisselli et al. (2003) conducted a study on organic cultivation of strawberry and reported that the plant health was satisfactory but the yield of organic strawberry was lower than that of conventionally produced crop and the production cost was also 30-40% high over conventional.

Arancon et al. (2004) reported that application of vermicompost on strawberry cv. Chandler resulted the highest yield (150 q/ha), fruit weight (10.2 g) and width (20.19 mm).

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).

Ilgn et al. (2006) reported that application of F.Y.M. (15 t/ha) in strawberry cv. Douglas resulted highest yield/plant.

Nowsheen et al. (2006) reported that application of P.S.B. (5 kg/ha) in strawberry cv. Senga Sengana resulted highest yield (230.95 g/plant). They further reported observed that application of Azotobacter (4 kg/ha) on strawberry cv. Senga Sengana resulted highest yield (235.90 g/plant).

Ramesh et al. (2008) reported that the field experiment to study the effect different organic manures viz., vermicompost, phosphocompost, poultry manure and cattle dung manure against chemical fertilizers on the productivity, nutrient uptake and soil fertility of maize, linseed cropping system. The result indicate that application of
chemical fertilizer resulted in highest maize grain yield (5122kg/ha), where as poultry manure application recorded the highest seed yield of linseed (1025kg/ha).

Singh and Singh (2009) reported that the combination of *Azotobacter* +Azospirillium + 60 kg N ha$^{-1}$ + 100 ppm GA$_3$ improved yield parameters viz. berry length (4.53cm), berry weight (16.75 g) and fruit yield (94.26 q ha$^{-1}$) in strawberry fruits cv. Sweet Charlie.

Tuzel *et al.* (2009) reported that strawberry plants can be grown better in soil amended with poultry manure as a fertilizer but application rate and availability of all minerals should be considered. Strawberry plants grown in soil amended with poultry manure showed a vigorous vegetative growth (leaf area, fresh and dry weight), high yield and large fruit weight compared with chemical fertilizer. Further studies are needed to determine optimal rates to be used for proper growth and production of strawberry.

Yadav *et al.* (2010) reported that the *Azotobacter* inoculated treatments was significantly increased in yield parameters viz. no. of berries (22.27/plant) and fruit yield (101.99 q/ha).

Dadashpour and Jouki (2012) studied the experiment comprised of five organic nutrient treatment combinations including the recommended dose of N, P and k through chemical fertilizer as control. Treatment N2 (manure + *Azotobacter*+ woodash+ Phosphorus solubilizing bacteria + oil cake) improved significantly yield (238.95g/plant).

Verma and Rao (2013) studied that *Azotobacter* + PSB+ Vermicompost+ 50% RDF gave the best yield attributes in strawberry cv. Chandler.

### 2.4 Quality attributes

Rana and Chandel (2003) reported significant effect of nitrogen on fruit quality of strawberry. They found that increased level of nitrogen improved total soluble solids and total sugar of fruits.

Sahoo and Singh (2005) reported that soil application of different levels of bio-fertilizers (*Azotobacter, Azospirillum*) on strawberry cv. Sweet Charlie, have
significantly effect on quality attributes of strawberry fruits. TSS (8.6 °Brix) were enhanced with the application of 6 kg *Azotobacter* per ha.

El-Hamid *et al.* (2006) reported that application of P.S.B. on strawberry resulted increase in T.S.S., total sugar, ascorbic acid and juice percentage.

Singh *et al.* (2008) studied the effect of vermicompost on strawberry Cv. ‘chandler’ and reported that fruit harvested from plant receiving vermicompost were TSS and ascorbic acid increases, acidity decreased and color more attractive.

Iqbal *et al.* (2009) noticed that the fruit quality viz. total soluble solids, total sugars, ascorbic acid and anthocyanin content was highest in fruits obtained from plants supplied with 25 per cent nitrogen through FYM + 75 percent nitrogen in the form of Urea+ Azotobactor.

Kirad *et al.* (2009) reported that the quality parameters of strawberry were increased with decreasing level of chemical fertilizers. Maximum plant height and acidity were recorded with the application of recommended fertilizers rate along with 25% vermicompost.

Singh and Singh (2009) reported that the combination of Azotobacter +Azospirillium + 60 kg N ha⁻¹ + 100 ppm GA₃ improved quality parameters viz. TSS (8.96°B), Ascorbic acid (59.22 mg/ 100g fruit pulp) in strawberry fruits cv. Sweet Charlie.

Tripathi *et al.* (2010) applied 5, 6 and 7 kg each of *Azotobacter*, Azospirillum and PSB in strawberry cv. Chandler and reported that the soil application of *Azotobacter* at 7 kg per ha. Significantly increased the maximum length (3.55 cm), width (2.35), weight (7.23 g), TSS (9.13°Bri), total sugars (8.20%) and ascorbic acid (56.01 mg/100g edible material) contents in berries in comparison to untreated plants.

Dadashpour and Jouki (2012) studied the experiment comprised of five organic treatment combinations including the recommended dose of N, P and k through chemical fertilizer as control. Treatment N2 (Poultry manure + *Azotobacter*+ woodash+ Phosphorus solubilizing bacteria + oil cake) improved significantly quality
of fruit about diameter (3.11cm), length (3.95 cm), volume (20.397 cm$^3$), weight (11.11g), total sugars(7.95%), total soluble solids (TSS) (9.01$^\circ$Brix), acidity (0.857).

Rayees et al. (2015) reported that 0% recommended dose of inorganic fertilizers + 100% recommended dose of manures gave the best quality of strawberry fruit above TSS (14.00$^\circ$B), Ascorbic acid (53.6 mg/ 100ml fruit pulp) , pH (2.81) and Specific gravity (1.30).

2.5 Soil parameters:

Wang and Lin (2002) reported that compost significantly enhanced strawberry plant growth and fruit quality when used as a soil supplement.

Ganie et al. (2008) reported that the long term sustainability of agriculture and in turn the life of biosphere is a very large extent dependent upon the soil health. The soil is regarded to be the microbial complex which supports and enriches plant growth. The continuous production of mulberry for a long time results in gradual reduction of leaf yield and quality.

Yavari et al. (2008) reported that the need for optimizing the tested organic growing media in order to increase the nutrient acquisition and utilization efficiency of the plants and also release the conclusion that improved organic growing media can supply most of the necessary plant nutrients needed for the plant, thus limiting the need for supplementary fertilization and being an alternative to conventional production with inorganic fertilization.

Verma and Rao (2013) reported that the effect of integrated nutrient management on growth, yield of strawberry cv. Chandler and nutrient status of soil under mid hill conditions of Uttarakhand with twelve treatment combinations comprising of inorganic fertilizers (N:P:K), biofertilizers (Azotobacter and PSB) and organic manures (FYM and Vermicompost) replicated thrice with 20 plants per replication in randomized block design. Observation were recorded for vegetative growth, fruit yield and chemical properties of soil. The application of Azotobacter + PSB + Vermicompost + 50% RDF was found to more effective in decreasing the electrical conductivity (0.02 dSm$^{-1}$) and pH (6.27) of soil. The organic carbon (1.95
%), available nitrogen (314.64 kg ha$^{-1}$), phosphorus (17.56 kg ha$^{-1}$) and potassium (306.33 kg ha$^{-1}$) were recorded significantly higher in soil after harvest of the crop in treatment receiving $Azotobacter$ + PSB + Vermicompost + 50% RDF.