REVIEW OF LITERATURE

Chapter II

Strawberries are good source of vitamin and minerals (**Singh *et al*., 2007**). In India, during last decade, it has become favourite fruit among growers because of its remunerative prices and higher profitability. Further, availability of day neutral and high yielding varieties has resulted in phenomenal increase in its area (**Sharma *et al*., 2004; Paramanick *et al*., 2005**).

Fragaria is a genus of perennial, creeping, herbs found growing in the wild in different climatic zones of the world. Strawberries are known for their characteristics aroma, which is attributed to the presence of volatile esters. The most important aroma compounds are ethyl hexanoate, methyl hexanoate, ethyle heptanoate, ethyle propionate, ethyle butanoate and furanoane. However, concentration of these compounds varies among cultivars and thus the aroma also. The ripe fruit of strawberry contain slightly more lipid than unripe ones; with higher quantity of oleic acid and lesser of linoleic acid (**Mitra, 1991)**. Essential oil can also be extracted from strawberry leaves. The major constituents of strawberry oil are linalool and nonanal (**Khanizadeh and Belanger, 1993**). The ripe strawberries attain attractive red colour on maturity and have soft, melting pulp of a characteristics flavour. The red colour of the fruit is mainly due to the presence of an anthocyanin, pelarogonnidin 3-monoglucoside, and trace of cyanidin (**Singh and Sharma, 1970; Pathak and Singh, 1971a, Mitra, 1991**).Citric acid is the most abundantly found organic acid, followed by malic acid, succinic acid and oxalic acid. These acids determine pH, colour stability and inhibit enzyme activity of strawberry fruit. Strawberry fruit contains polyphenols, like chloroginic acid, catechin and coumaric acid, the contents of the phenolic compounds, however decreases as fruit ripens; due to the synthesis of anthocyanins (**Cheng and Breen, 1991**). Among various factors which contribute on growth, yield and quality of strawberry, nutrition is one of the most important aspects of crop production. Application of organic manure viz., vermicompost not only improve the soil's physical properties (water holding capacity, soil aeration, drainage and water retention capacity) but also prevent soil degradation and increases important microorganism population. Biofertilizer like *Azotobactor*, fix atmospheric nitrogen and solubilise phosphorus to increase soil fertility and help plant growth and yield by increasing their number and biological activities. *Azotobacter* stimulation of plant development, the exact mode of action by which *Azotobacter* enhances plant growth is not yet fully understood. Three possible mechanisms have been proposed: N_2 fixation, delivering combined nitrogen to the plant; the production of phytohormone-like substances that alter plant growth and morphology, and bacterial nitrate reduction. *Azotobacter* is capable of converting nitrogen to ammonia, which in turn is taken up by the plants (**Kamil *et al*., 2008**).

Vermicompost is a finely-divided mature peat-like material which is produced by a non-thermophilic process involving interactions between earthworms and microorganisms (**Edwards and Burrows 1988**).The beneficial effect of vermicompost was first highlighted by **Darwin (1881).**Vermicompost contains micro site rich in available carbon and nitrogen (**Sudhakar *et al.,* 2002**). Application of vermicompost, decreased particle density but, increased water holding capacity of the soil. Variation in water holding capacity of soil could be attributed to the addition of organic matter, difference in quantity and nature of colloidal materials present, pH and salt contents of the soil due to vermicompost application (**Macit *et al*., 2007**). Vermicompost is very high in organic matter (20 – 80%) and humic substances that contain numerous carboxyl, hydroxyl and ketony functional groups. It forms water stable aggregate, held together by polysaccharide gums from the earthworm's digestive system and associated microbial activity, plant fibers, fungal hyphae and organo-mineral bonds. These aggregates tends to improve the physical structure of soil or plant media when used as an amendment to the growth medium. In a comparison of vermicompost derived from different animal manures and solid household waste, water stable aggregates and water holding capacity increased in a linear manner with the addition of increasing rates of vermicompost (**Ferreras *et al.,* 2006**). In substitutions made with vermicompost to a standard peat based greenhouse medium such as Metro-Mix 360, a significant increase was seen in bulk density, water holding capacity and the number of microspores, while the number of macrospores, total percent porosity and total percent air space decreased (**Atiyeh *et al*., 2001**). However, in studies combining vermicompost with soils, bulk density and particle density decreased while total percent pore space and water holding capacity increased (**Llaven *et al.,* 2008**). Good aggregate structure in a growing medium is important as it provides numerous microsites for microbial activity and the adsorption and release of plant available nutrients, extracellular enzymes and Plant growth regulators (PGRs) through interaction with plant root exudates (**Aira *et al*., 2007; Nardi *et al*., 1996**). The chemical characteristics of vermicompost depend largely on the composition of the starting material. The pH of vermicompost derived from cattle manure and plant residues, coffee pulp, pig manure and sheep manure was 6.0-6.5, 7.0, 5.3, 8.6, respectively (**Atiyeh *et al*., 2000; 2001, Jordao *et al*., 2002; Orozco *et al.,* 1996)**. Nitrate is a form of nitrogen most prevalent in vermicompost (**Atiyeh *et al*., 2000; Chaoui *et al*., 2003, Orozco *et al.,* 1996**). Total percent N is usually under 2.5% (**Buckerfield *et al*.,**

1999). The C: N ratio is usually under 20:1 (**Orozco *et al*., 1996**). Most plant available nutrients were found to increase during the vermicomposting process. In coffee pulp, an increase in soluble P, Ca and Mg was found, and N increased from 3.0% to 3.2- 3.6% (**Orozco *et al*., 1996**); however, there was a decrease in K, possibly due to leaching in outdoor worm beds, and the Mg/K ratio was considered to be too low (**Orozco *et al.*, 1996**). In raw dairy manure, there was a decrease in N and K, possibly due to volatilization of ammonia and leaching of these nutrients in outdoor beds, and an increase in all micronutrients and total P, although soluble P decreased. An increase in phosphorus is most consistently seen in vermicompost, possibly due to phosphatase enzymatic activity in the worm gut (**Albiach *et al.*, 2000**). Nutrients for vermicompost usually fall within the range of (based on dry weight) 2.2%-3.0% N, 0.4%- 2.9% P, 1.7%-2.5% K and 1.2%-9.5% Ca (**Edwards *et al.*, 2011**). For organic growers, vermicompost shows promise as a fertility source, although some have argued that for optimum plant growth, some other nutrient source should also be added along with vermicompost (**Arancon 2003**). However, there is evidence that the effect of vermicompost on plant growth cannot be attributed to fertility alone. Enhanced microbial activity in soils with the addition of Vermicompost is known to increase the production of PGRs and extracellular enzymes such as urease, phosphotase and protease (**Aira *et al*., 2007; Bernitez *et al.*, 2004)**, which can be adsorbed together with ions, onto negatively charged sites on humus surfaces, and protected in aggregate microsites from microbial degradation. This allows extracellular enzymes, ions and PGRs to persist in the soil or growth medium until they can be released by organic acids in plant root exudates (**Nardi *et al*., 1996**). Plants grown with humic fractions derived from vermicompost, especially of low molecular weight (<3500 MW), have increased root elongation and lateral root formation (**Canellas *et al.*, 2010**), stimulated H+ ATP ashes and plasma membrane permeability and enhanced nitrogen assimilatory enzymes. This may account for the increased plant growth and yield observed with additions of vermicompost when all recommended nutrients are supplied inorganically (**Atiyeh *et al*., 2001**).This biological influence observed in vermicompost is attributed to its microbial population which is rich in actinomycetes and fungi (**Anastasi *et al*., 2004**), both sources of PGR. This positive influence of vermicompost on plant growth can also be attributed to a more direct microbial effect and in recent experiments, some biological activity against horticultural diseases and pests has been found. In several studies, adding vermicompost to the soil or greenhouse medium decreased the incidence of gray mould and botrytis on strawberries (**Singh *et al.*, 2008**). Application of vermicompost stimulates root growth and facilitates nutrient absorption, and hence favours higher percentage yield. Therefore, vermicompost generally contains higher and more soluble levels of major nutrients required for plant growth such as nitrogen, phosphorus, potassium, calcium and magnesium as compared to normal compost. (**Padmavathiamma *et al*., 2008**). The result suggests that biologically active plant growth-influencing substances appeared as plant growth regulators or humic acids in the vermicompost, which were also responsible for improving plant growth. (**Arancon *et al*., 2003**).The use of bio-fertilizers is being sought to maintain and improve soil quality and productivity levels at low input costs. Bio-fertilizers containing beneficial microorganisms instead of synthetic chemicals are known to improve plant growth through supply of plant nutrients and may help to sustain environmental health and soil productivity (**Connell, 1992**). Use of organic sources of nutrients helps to conserve the soil health by maintaining the equilibrium of organic matter and soil micro flora ultimately helping to improve physical, chemical and biological properties of the soil (**Walia and Kler, 2009**).

Keeping these facts in mind the present investigation entitled **"studies on the efficacy of vermicompost, urea and *Azotobacter* on growth, yield and quality attributes of strawberry (*Fragaria* x *ananassa* Duch.)"** was carried out under field conditions. A brief review of available research findings on nutrient management in different crop with special emphasis to fruit crop is being presented here.

2.1 Effect of Vermicompost, Urea and *Azotobacter* on vegetative growth parameters

Arancon *et al*. (2002) conducted experiment on vermicompost processed from food wastes and paper wastes in Ohio state conditions under high plastic hoop tunnels. The vermicompost was applied at the rate of 5-10 tonnes per ha and incorporated into the top 10 cm of soil. Vermicompost treated plots were supplemented by inorganic fertilizers only to equalize the initial fertilizer rates of 85-155-125 kg/ ha NPK. They reported that vermicompost significantly increased leaf area (37 %), number of runners (36 %), and number of flowers (40 %) in strawberry cv. Chandler as compared to other sources. This response could have been due to production of plant growth regulators by micro organisms during vermicomposting.

Arancon *et al*. (2003) observed that application of vermicompost of 20 tonnes per ha in strawberry recorded increased leaf area, number of flowers, number of runners and shoots per plant.

Arancon *et al*. (2004) further reported that there was significant increase in growth and yield parameters like leaf area, plant shoot biomass, number of flowers, number of plant runners and marketable fruits weight by the applications of vermicompost as compared to inorganic fertilizers in strawberry.

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.

Sara *et al.* (2013) reported that application of vermicompost improved fresh leaf weight (0.92 g), number of leaves (6.67), leaf area (43.07 cm^2) and days required for first fruit bloom (96.67).

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

Vadiraj *et al*. (1993) noticed a significant increase in plant height, number of leaves fresh and dry weight of cardamom seedling when vermicompost was used as potting mixture.

Tripathi *et al*. (2010) found that the soil application of 7kg per ha. *Azotobacter* significantly increased the plant height (16.05cm), number of leaves (54.75), number of runners (4.39).

Yadav *et al.* (2009) concluded from his work that the majority of plant growth parameters of strawberry like number of flowers, number of fruits, number of runners, and fruit yield were recorded maximum in *Azotobacter* inoculated treatments with 50% nitrogen substitution by vermicompost and remaining 50% through inorganic fertilizers.

Wang (1996) summarized that inoculation of *Azotobacter* in strawberry Cv.Sujata increased number of leaves, buds, flowers and fruits per plant.

Singh *et al*. (2008) used vermicompost prepared from vegetable waste mixed with cow dung an applied it as four treatments (at the rates of 2.5, 5.0, 7.5 and 10 t/ha) on strawberry (*Fragaria x ananassa* Duch.) in the field. Treatment with recommended dose of inorganic fertilizers was used as control. Plant spread and plant dry weight was found to be higher in vermicompost treatments as compared to inorganic fertilizer treatment. After 180 days of planting, plant spread was observed to be 12.7 cm in inorganic fertilizer treatment, while it was found to be 12.5, 13.0, 13.9 and 13.8 cm in treatments with vermicompost applied at the rates of 2.5, 5.0, 7.5 and 10 t/ha, respectively. Increase in plant spread in all vermicompost treatment was statistically significant as compared to inorganic fertilizer treatment. Similarly, plant dry weight was significantly higher in all treatments of vermicompost as compared to control (inorganic fertilizer).

Atefe *et al.* (2012) indicated that application of vermicompost in substrate improved indexes of yield. The highest of diameter of crown (19.45mm), fruit length (4.47 cm), and yield (264.14 g).

Rajbir *et al*. (2008) concluded that application of vermicompost on strawberry cv.Chandler resulted that increased plant spared (10.7%), leaf area (23.1%), and total fruit yield (32.7%).

Manikuntala and Subhash (2014) reported that application of vermicompost in strawberry resulted that plant height (23 cm), leaf petiole (14.73 cm), number of runners (7.10), bush diameter (25.12 cm), number of flowers (20,12), fruit yield (209.49 g) per plant

Ghaderi and Talaie (2008) showed that application of manure along with urea had a significant effect on total fruit yield, and prevention of weight, fruit decay as well as leaf specific mass. Fruit quality is a combination of appearance, flavour, texture and nutritional value.

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), number of leaves (63.60), number of runners per plant (5.34) and maximum number of flowers (64.51).

Singh *et al*. (2015) observed plant height (14.83, 15.86 cm), plant spread (19.69, 18.76 cm), number of leaves per plant (37.84, 38.82), leaf area (88.01, 88.81), numbers of runners per plant (3.27, 4.72) and numbers of flower per plant (47.06, 49.15) with the application of vermicompost at 10 tonnes per ha and *Azotobacter* at 7 kg per ha in strawberry, respectively. Whereas, combined application of vermicompost (10 tonnes/ha) and *Azotobacter* (7 kg/ha) significantly increased the plant spread (22.11 cm), number of leaves per plant (52.17), leaf area (96.70), numbers of runners per plant (5.38) and numbers of flower per plant (53.83).

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.

Wange *et al*. (1998) reported microbial inoculation of *Azotobacter* significantly increased the number of leaves per plant and number of buds per plant in strawberry.

Rana and Chandel (2003) used biofertilizers 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.

Chol *et al*. (2000) found that nitrogen uptake increase the fresh weight and recommended 80-110 mg per litre of concentration of nitrogen to achieve highest crop growth in ‘Nyoho’ strawberry.

Umar *et al.* (2010) claimed that application of 25% nitrogen through subabul + 75% nitrogen in the form of urea augmented with bio fertilizer resulted in maximum plant height (20.9cm), plant spread(27.8cm) and leaf area(70cm^2) in strawberry cv. Chandler.

Arancon *et al*. (2002) conducted experiments on vermicompost processed from food wastes and paper wastes in Ohio state conditions under high plastic hoop tunnels. The vermicompost was applied at the rate of 5-10 tonnes per ha and incorporated into the top 10 cm of soil.

Vermicompost treated plots were supplemented by inorganic fertilizers only to equalize the initial fertilizer rates of 85-155-125 kg per ha NPK. They reported that vermicompost significantly increased leaf area (37%), number of flowers (40%), and number of runners (36%) in strawberry cv. 'Chandler' as compared to other sources. This response could have been due to production of plant growth regulators by micro organisms during vermicomposting.

Darrow and Waldo (1932) studied that nitrogen (Urea), especially if applied in the spring, has a tendency to increase number of leaves and leaf area per plant of strawberry.

Tripathi and Babu (2008) observed that application of *Azotobacter* at 6 kg per ha significantly increased the height of plant, number of leaves, crown, runners, number of flowers and fruits per plant.

Yusuf *et al*. (2003) carried out a field experiment in Azad Kashmir in Pakistan during 1999-2001 to determine the effect of single or combined application of NPK(150:100:100kg) per ha and vermicompost 5 tonnes on the field of strawberry cv. Tuft. Combined application of NPK (150:100:100 kg) per ha with vermicompost 5 tonnes per ha resulted in the highest number of leaves, number of flowers, fruit set and number of fruits per plant.

Zargar *et al. (*2008) noticed that combination of nitrogen (225 kg ha-1), phosphorus (150 kg ha-1) and *Azotobacter* showed highest values of average fruit weight (19 g), plant height (40.66 cm), significantly affected number of primary flowers (8.0), number of secondary flowers (10.00), total number of flowers per plant (18.00), number of primary fruits per plant (7.00), number of secondary fruits (10.00) and total number of fruits (17.0).

Pandit *et al.* (2015) recorded application of *Azotobacter* 5 kg per ha in strawberry cv. Chandler resulted that total number of flowers per plant (23.09), total number of fruits per plant (21.37),fruit length (1.29 cm) obtained from *Azotobacter* treated plants.

Singh *et al*. (2012) noticed plant height (18.07 cm) and runners per plant (4.83) in strawberry cv. Senga Sengana by the application of vermicompost (5 tonnes per ha).whereas combined application of vermicompost (5 tonnes per ha) and *Azotobacter* (20 g) per plant resulted plant height (19.37 cm) and number of runners per plant (5.66).

Yadav *et al.* (2009) observed maximum plant height, number of leaves, number runners and number of fruits per plant recorded in *Azotobacter* inoculated plant with 50 % N substitution by vermicompost and remaining 50 % through inorganic fertilizer in two equal splits at establishment and before flowering stage.

Godara and Awasthi (2008) revealed from his study that the number of leaves and number of flowers plant of peach increased significantly with inoculation of *Azotobacter* strains as compared to untreated *Azotobacter* strains.

Lata *et al*. (2013) reported that maximum plant height, number of leaves per plant, length of leaves, and width of leaves per plant in strawberry was recorded with the combined application of *Azotobacter* 50% + *Azospirilum* 50% + NPK 50%.

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).

Miquelao *et al.* (1994) observed that 36 % more runners production in strawberry cv. Chandler by the application of urea than the unfertilized control plants.

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.

Rajbir *et al*. (2008) concluded that application of vermicompost on strawberry cv.Chandler resulted that increased plant spared (10.7%), leaf area (23.1%), and total fruit yield (32.7%).

Verma and Rao (2013) conducted an experiment to see 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. Treatment receiving *Azotobacter* + PSB + vermicompost + 50% recommended dose of NPK recorded highest plant height plant spread, leaf area per plant. Plant supplied with *Azotobacter* + PSB + vermicompost + 50% RDF registered earliest in flowering and fruit maturity and highest number of flowers per plant and flowering duration.

2.2 Effect of Vermicompost, Urea and *Azotobacter* yield parameters

Turemis (2000) carried out an experiment to find out the effect of various plant compost and manure on yield and quality of strawberry cv.Dorit. He reported highest yield with the vermicompost treatment (595.4 g per plant), followed by wheat straw + poultry manure with (490.2 g per plant), Tobacco + poultry manure (464.6 g per plant), Banana leaf + FYM (456.9 g per plant) and poultry manure only (436.6 g per plant).

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

Hameedunnisa, (2000) observed the response of tomato crop to *Azotobacter* inoculation which increased the yield.

Arancon *et al*. (2004) found 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).

Rana and Chandel (2003) observed 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) and fruit weight (9.11 g).

Wasi Amiri *et al*. (2011) examined that effect of bio-inoculants (*Azotobacter)* on growth of strawberry 'Sujatha' resulted to increase in plant height, number of leaves per plant and leaf area.

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), berries with maximum length (5.01 cm), berries with maximum width (2.64 cm), weight (9.02 g) and volume (6.12 cc).

Singh *et al*. (2015) projected that fruit yield of strawberry per plant (159.13, 164.90 g) with the application of vermicompost at 10 tonnes per ha and *Azotobacter* at 7 kg per ha, respectively. Whereas, combined application of vermicompost (10 tonnes/ha) and *Azotobacter* (7 kg/ha) significantly increased the fruit yield per plant (210.90 g).

Mehraj *et al.* (2014) observed significantly increased number of flowers per plant (22.70), number of fruits per plant (19.20), fruit weight (14.40) and fruit yield per plant (282.80 g) with the application of vermicompost as compared to cow dung and poultry litre.

Singh *et al*. (2010) reported fruit length (27.42 mm),fruit diameter (25.92 mm),fruits per plant (9.15),fruit weight (8.45 g)and berry yield (4.54 tonnes) per ha with the application of *Azotobacter chrococcum* at 1 litre broth per 1000 runners of strawberry cv.Senga Sengana.

Umar *et al.* (2010) observed significantly increased fruit size (28.9mm),fruit weight(19.6 g) and fruit yield (385.2q/ha) with the application of 25% nitrogen through subabul + 75% nitrogen through urea in strawberry cv. Chandler.

Pandey and Mishra (1983) recorded that 75-100kg nitrogen, 80-120kg phosphorus and 50-75kg potash per ha results in best growth, highest fruit yield and better quality in strawberry.

Verma and Rao (2013) found that the maximum fruit weight, number of fruits per plant, yield per plant (181.84 g), marketable yield per plant (145.47 g) and yield per hectare (101.02 q) were recorded with plants treated with *Azotobacter* + PSB + vermicompost + 50% RDF followed by *Azotobacter* + PSB + FYM + 50% RDF treatment. 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}), phosphorous (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

Singh *et al*. (2012) noticed fruit weight (8.10 g) and fruit yield (6.05 tonnes per ha) in strawberry cv. Senga Sengana by the application of vermicompost (5 tonnes per ha). Whereas combined application of vermicompost (5 tonnes per ha) and *Azotobacter* (20 g per plant) resulted berry weight of 8.48 g and fruit yield 6.39 tonnes per ha.

Shinde *et al*. (1995) concluded that a field experiment was conducted on a medium texture calcareous soil to assess the effect of vermicompost and FYM or the yield uptake N, Fe, Mn and Cu by strawberry, revealed that application of FYM at 20 tonnes per ha was found beneficial for strawberry crop due to yield and uptake of N, Fe, Mn, and Cu were increased. Non- significant difference of strawberry was noted due to application of vermicompost at 5 and 7.5 tonnes per ha. However, the yield of strawberry was increased by 10 % as compared to control due to application of vermicompost.

Derevyanchuk (1977**)** confirmed that strawberry grown on dark gray forest soil. Application of urea (N) gave the highest yields compared with several other N forms.

Joolka *et al.* (1986) recommended fertilizer dose of 150 kg N with 75 kg P_20_5 per ha observed higher yield of strawberry.

Gariglio *et al*. (2000) observed N treatments significantly increases yield of strawberry over the control. Yield increased to increasing N rates from 0 to 53 kg/ ha, this response was an increase in fruit number but not in fruit weight.

Locascio and Martin (1985) found 100% N application through urea before planting of strawberry significantly increased the marketable fruit number and fruit weight.

Atif Yasseen Mahadeen (2009) concluded that application of NPK-fertilizer in combination with organic fertilizer tended to increase fruit yield in comparison with the application of each of them alone. The highest strawberry yield (27.62 ton/ha) was obtained by the application of 40 tons of organic fertilizer with 60 kg NPK-fertilizer/ha while the lowest strawberry yield (21.76 ton/ha) was obtained in untreated plot. Addition of 0 and 20 kg/ha NPK fertilizer without organic fertilizer produced significantly lower strawberry yield compared with other treatment combinations. It was clearly evident that all treatments that received organic fertilizer recorded higher strawberry yield when compared with untreated plots with organic fertilizer, which indicated the importance of organic fertilizer. Number of fruits per plant was significantly decreased by adding organic fertilizer (40 ton/ha) even with combination of chemical fertilizer. On the other hand, average fruit weight was significantly increased with addition of organic fertilizer with or without chemical fertilizer the percent increase in average fruit weight due to organic fertilizer application was about 24% higher when compared with the application of NPK-fertilizer alone.

2.3 Effect of Vermicompost, urea and *Azotobacter* on quality parameters

Sahoo and Singh (2005) observed that soil application of different levels of biofertilizers (*Azotobacter*, *Azospirillum*) on strawberry cv. Sweet Charlie, have significantly effect on quality attributes of strawberry fruits. T.S.S (8.6 ^{0}Brix) were enhanced with the application of 6 kg Azotobacter per ha.

Azarmi *et al.* (2009) reported that fruits harvested from plants that received vermicompost had significantly greater total soluble solid (TSS) than those harvested from the mineral fertilizer plot.

Singh *et al*. (2008) found that the application of vermicompost in strawberry enhanced the ascorbic acid content, pH of fruit, and total soluble solid of fruit.

Gupta and Tripathi (2012) recorded total soluble solid (10.31 ^{0}Brix), total sugars (9.73%), ascorbic acid (56.52 mg/100g edible pulp) with minimum titratable acidity (0.52%) with combined application of *Azotobacter* at 7 kg/ha+ vermicompost at 30 tonnes/ha.

Mehraj *et al.* (2014) observed significantly higher total soluble solids (10.20 ^{0}B) with the application of vermicompost as compared to cow dung and poultry litre.

Umar *et al.* (2010) summarized that application of 25% nitrogen through subabul + 75% nitrogen in the form of urea augmented with bio fertilizer resulted in maximum total soluble solid (6.836 ^{0}Brix), total sugars (4.85%) in strawberry cv. Chandler.

Badiyala and Bhutani (1990) had recorded total soluble solids (8.13%) and lowest acidity with the fertilizer schedule consisting of 150kg N 75kg P and 50kg K per ha. in strawberry cv. Tioga in mild hills areas (palampur) of Himanchal Pradesh.

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

Rana and Chandel (2003) ascertained that inoculation of *Azotobacter* with 80 kg N/ha in strawberry cv.Chandler resulted in maximum T.S.S. content (8.78 ^{O}Brix), whereas maximum total sugar (7.65%) was recorded in the fruits obtained from *Azotobacter* inoculated plants.

Yoshida *et al*. (2002) assessed that anthocyanin synthesis in strawberry fruits may be reduced by N deficiency.

Panova *et al*. (1976) carried out an experiment on strawberry cv. Festival Naya and Kamsomolka with the application of NPK at 100:60:80 kg per ha along with vermicompost at 5 tonnes per ha. The addition of N increased fruit sugar constant but decreased total acidity. Different type of nitrogenous fertilizers did not differ in their effect on fruit chemical composition.

Pandit *et al.* (2015) conducted application of *Azotobacter* 5 kg per ha in strawberry cv. Chandler resulted that total soluble solids (9.65 ^{0}Brix) and acidity content of fruits (0.70%) obtained from *Azotobacter* treated plants

Lacertosa *et al*. (1999) assured that ascorbic acid and sugar concentrations were inversely correlated with the content of nitrogen in the fruits, indicating that proper N fertilizer application could be effective in improving fruit quality of strawberry.

Kopanski and Kawecki (1994) showed that N application of 90 kg N per ha increased the vitamin C content of ‘Dukat’ and ‘Senga Sengana’ cultivars of strawberry.

Haynes and Goh (1987) opined that the effect of N applications on titratable acidity and sugar content of strawberry fruits are inconsistent and vary from year to year.

Kumar *et al*. (2015) applied combined application of vermicompost (250 g) per plant and *Azotobacter* (2 g) per plant in strawberry cv. Chandler and observed total soluble solid (9.85

^{O}Brix), titratable acidity (0.95%), ascorbic acid (53.75 mg/100g), reducing sugar (4.60 %) and total sugars (5.91%).

Shehata *et al.* (2011) revealed that, by using compost the amounts of total soluble salt and anthocyanin levels in strawberry fruit have increased in greater extent with respect to chemical fertilizer.

Atif Yasseen Mahadeen (2009) evaluated that vitamin- C content of strawberry fruit showed a significant increased with application of organic fertilizer when compared with untreated plots with organic fertilizer. Application of 40 tons of organic fertilizer per ha with or without chemical fertilize resulted in increased vitamin C content of strawberry fruit about two times when compared with untreated plots with organic fertilizer.

Asami *et al*. (2003) observed that application of vermicompost and organic fertilizers increased vitamin- C in strawberry.

Pandit *et al.* (2015) found that application of *Azotobacter* 7 kg per ha in strawberry cv. Chandler resulted total sugars (4.70 %), reducing sugar (3.30 %), non-reducing sugar (1.33%) and vitamin-C (46.11 mg/100 g) was recorded in the fruits obtained from *Azotobacter* treated plants.

Singh *et al*. (2012) confirmed that T.S.S. (9.75 ^{0}Brix), titratable acidity (0.534%), total sugars (7.06%) and ascorbic acid (49.59%) by using vermicompost (5 tonnes per ha) in strawberry cv. Senga Sengana. Whereas, combined application of vermicompost (5 tonnes per ha) and *Azotobacter* (20 g per plant) resulted T.S.S. (9.86 ^{0}Brix), titratable acidity (0.523 %), total sugars (7.37 %) and ascorbic acid (49.96 %).

Asghari (2014) found the increased the best percent of biochemical characters of strawberry (total soluble solids, titratable acidity and anthocyanin) was observed with application of vermicompost + perlite + coco peat (30:60:10) without chemical fertilizer.

Ameri *et al.* (2012) registered highest total anthocyanin (222.65 mg/ 100 g) content in Camarosa strawberry and vitamin-C (108.05mg /100 g) in Selva strawberry by the application of vermicompost + perlite + cocopeat (15:40: 45). The highest total soluble solid in Selva (8.66 ^{0}Brix) and titratable acidity in (2.87 mg / 100 g) Camarosa cultivar was recorded with the application of vermicompost + perlite + cocopeat (5:45:50).

Leskinen *et al.* (2002) recorded that organic grown strawberry had more sugar than conventional grown.