CHAPTER II

Review of Literature
CHAPTER – II

Review of literature

The most common goal of intercropping in fruit orchards is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a sole crop. Careful planning is required, taking into account the soil, climate, crops, and varieties. This is essential because the roots of such trees may start competing with the roots of main fruit trees for nutrients and moisture. The filler trees, unless removed at appropriate time when primary fruit trees start giving economic crop, may create problems of low orchard efficiency.

In this chapter the observations made by the previous workers have been reviewed and authors are duly acknowledged.

2.1 Inter cropping in mango orchard

Singh (1968) suggested that crop combination of cowpea, cucurbits, spinach, okra, cabbage, beet root, onion, carrot and cauliflower intercrops with mango was beneficial.

Hardwood and Price (1976) reported that upland rice, maize, cassava, soybean, etc. were grown in newly established mango orchard in Philippines, because in the first few years after planting of the trees, there was little interference in light interception.
Bhuva et al. (1988) studied the effect of intercropping on the main crop of mango and the economics was studied on mango cv. Rajapuri, planted at 6 mx 6 m and interplanted with (a) banana (b) cassava (c) tomato followed by cluster bean (d) brinjal followed by cowpea under south Gujrat condition. They opined that mango grown with tomato and cluster bean as intercrops gave greatest financial return per hectare with benefit-cost ratio of 1.22.

Singh et al. (1995) reported the nutritional status of ‘Dashehari’ mango as influenced by various intercropping. They obtained that leaf ‘N’ content was not affected by intercrops but increased with increasing mango tree age. However, the turmeric-radish treatment increased leaf ‘P₂O₅’ and ‘K₂O’ content.

Singh et al. (1996) studied the effect of cultural practices and intercropping on growth and economic yield of mango orchard cv. Langra at IGKV, Fruit Research Station, Bilaspur, Madhya Pradesh. The cultural practices and intercrops did not significantly affect the growth of plant in the initial year of planting, whereas significant differences were recorded in next year. All the treatments were significantly superior to sod culture except height of the plant in second year. Maximum net return was obtained with okra-gram-okra followed by chilli as annual crop in both the years. All other cultural treatments were un-economical. The growth of mango was not adversely affected by different treatments.

Rajput et al.(1998) stated that the initial investment required in establishment of mango orchard was high and beyond the economic reach of small and marginal farmers. So, during the pre-bearing stage, growing of intercrops has been advocated in order to get some additional income.
Bose et al. (1999) studied that the cultivation of intercrops in the alleys of young mango orchard was desirable for maximum land and space use efficiency to generate supplemental income during the juvenile phase of the orchard in West Bengal. Apart from giving good returns, intercropping prevents weed growth, reduce nutrient loss through leaching and surface runoff, keeps under control harmful diseases and pests.

Sharma (1999) studied the effect of intercropping on yield and economic viability of a 6 year old mango orchard (cv. Langra) intercropping with (1) okra in kharif, gram in rabi and then okra in summer, (2) soybean in kharif and chilli in rabi induced high levels of fruit drop of mango than mango grown alone, but the intercrops gave additional monetary returns and enhanced the profits.

Singh et al. (1999) conducted experiment to identify the suitable intercrops in rainy season for the bearing orchard of mango at CHES, Ranchi. Among the intercrops studied, cowpea produced significantly higher additional mango equivalent yield in both the years 17.13 quintal per hectare and 30.88 quintal per hectare respectively.

Singh et al. (2001) carried out an experiment to study the suitability and profitability aspects of intercrops in young mango orchard cv. Langra at Odisha. Among the different vegetable intercrops combination, the bottle gourd-radish combination increased the mango yield followed by lady's finger-carrot and chilli-onion with compared to control. The maximum net income (Rs.88,757.00 per hectare) was obtained from the bottle gourd-radish followed by sponge gourd and tomato (Rs.86,39.00 per hectare) combination.
Wangchu and Mitra (2002) reported that in a mixed fruit orchard consisting of six pummelo, seven sapota, five mango and three jackfruit trees in an area of about 0.4 acre yielded about 2500 kg fruits, which not only provided the requirements of the family but also showed an additional income of about Rs. 5000.00 per year from the homestead from the suitable intercrops like colocasia, tapioca, cowpea and turmeric in the homestead along with fruit in Arunachal Pradesh condition.

Nath et al. (2003) reported that soils of plateau region were generally poor in soil organic matter content and water holding capacity. Different intercrops had shown improving the percent organic matter and reducing the percent pore space in mango based cropping system. The soil organic matter increased significantly through the different intercrops. The cropping system with mango + lime + stylosanthes resulted in maximum soil organic matter 1.29% as compared to mango + no filler + fallow cropping system 0.81%. The mango + gram + paddy resulted in the minimum pore space in the soil 10.0%.

Baghel et al. (2004) stated that the intercropping of cowpea + bengal gram proved beneficial for increasing the yield (50.12 quintal per hectare ) of mango by 13.26% compared to clean cultivation, followed by pigeon pea + soyabeans and pigeon pea + black gram and intercropping of maize tomato and okra caused 11-19% mango yield losses compared to clean cultivation. Further, reported that the highest monetary returns Rs. 73,227.00 per hectare, net returns Rs.59,227.00 per hectare and cost benefit ratio 1:4.23 were obtained when pigeon pea+ tomato were grown in 2:2 paired rows as companion intercrops, followed by cowpea + bengalgram (Rs.52,660.00
quintal per hectare) and pigeon pea (Rs.50,767.00 quintal per hectare) alone as an intercrop in mango orchard of Madhya Pradesh, India.

Pandey et al. (2004) studied on various intercrops in five year old mango orchard 'Amrapali' and 'Mallika' at coastal Odisha. During rainy season of the year 2003, 25.75 quintal per hectare colocassia, 15.5 quintal per hectare amorphophallus, 21.33 quintal per hectare sweet potato, 58.2 quintal per hectare cluster beans, 45.24 quintal per hectare okra and 81.9 quintal per hectare cowpea could be harvested with additional bio-mass yield of 161, 142.6, 193, 55.83, 84.54 and 337.3 quintal per hectare respectively.

Sarkar et al. (2004) recorded the suitability and profitability of different vegetables in particular sequence as intercrop in young mango orchard under Deccan plateau at Fruit Research Station, Acharya N.G. Ranga Agricultural University, Medak, Andhra Pradesh. The study revealed that the growth of mango in early stages was not adversely affected by different intercrops. Among the intercrop rotations, brinjal in kharif and onion in rabi recorded highest benefit cost ratio. During the early age of mango tree, maximum fruit yield 10.60 kg per tree was recorded in cowpea-potato treatment. However, the brinjal-onion rotation produced 8.03 kg fruit per tree, which was at par with the control 7.90 kg per tree.

Ratha and Swain (2005) while working in a 6-year old mango (cv. Banganapalli) orchard in eastern ghat high land zone of Odisha to evaluate the suitability of the following crops as kharif intercrop of mango: ginger cv. Suprabha, french bean cv. Contender, cowpea cv. Pusa Barsati, tomato cv. BT-10 and rice cv. Pathara obtained the maximum average fruit number from
mango + french bean (80 fruits per plant) and mango + cowpea (75 fruits per plant) and the minimum was obtained from sole mango (47 fruits per plant).

Gill and Ajit (2006) studied for four years on intercropping with mango varieties (Amrapali, Mallika, Dashehari and Langra) planted in a spacing of 10m x 10m and raising oats in the inter spaces. The field study was carried out on sandy loam soil at the National Research Centre for Agroforestry, Jhansi (UP). Growth characters recorded in mango varieties prior to sowing of oat crop each year revealed the superiority of Langra followed by Mallika and Dashehari. Lowest growth characters were obtained with Amrapali. In case of grain yield of oats, it was highest in association with Langra cultivar of mango and lowest with Mallika.

Pandey et al. (2006) conducted an intercropping experiment in six and seven year old mango orchard at Odisha. The results revealed that improvement in soil pH (acidity towards neutrality) was negligible. Total available nitrogen (138.2 and 173.5 kg per hectare) and gross total gains of available nitrogen (19.5 and 45.9 kg quintal per hectare) after one year and two years of experiment were significantly maximum in cluster bean - chilli - bottle gourd cropping. The gross total available phosphorous (P2O5) was significantly maximum in colocassia - amaranthus - cowpea (105.6 kg per hectare) after one year and okra - frenchbean - watermelon (158 kg per hectare) after two year. The gross gain in available phosphorous was significantly maximum in okra-frenchbean-watermelon (61.6 kg per hectare) after one year and colocassia - amaranthus - cowpea (115.4 kg per hectare) after two years. The total available potassium (K2O) was significantly maximum in sweet potato - cowpea - amaranthus (286 kg per hectare) after one year and cowpea - tomato - okra (440 kg per hectare) after two years.
Significantly maximum gross total gains in available potassium in cowpea -
tomato - okra cropping after one year (144.6 kg per hectare) and two years
(161.9 kg per hectare) of experiment. Intercropping vegetables with balanced
fertilizer application in component crops improved the available phosphorus
and potassium contents of orchard soil from low level in the beginning to
medium and high level after two years.

Raut (2006) conducted a trial in the farmers field using various
intercrops paddy, maize, black gram and cowpea during kharif and gram,
wheat, peas and arhar in rabi season, for two years in 6-7 years old mango
orchard (cv. Langra and Dashehari). The result revealed that the average
number of panicles per branch of mango was found maximum (21.06) in paddy-
fallow intercropping system, the highest average fruit weight (238.9g per fruit)
and fruit yield was maximum (28 quintal per hectare) in arhar-arhar
cropping system.

Pawar et al. (2006) conducted trial in Maharashtra on intercropping
system of agronomic intercrops in fruit orchards to find out suitable
intercropping system. They reported mango + soyabean - gram gave the
highest plant height (4.59 m), plant spread (3.43 m), fruits per plot (66.83),
gross return (Rs. 21,089.00 per hectare) and net return (Rs 14,813.00 per
hectare).

Swain and Patro (2007) carried out an intercropping experiment in a
seven years old bearing mango orchard with filler crop guava revealed that
the maximum increase in plant height, girth and canopy area of mango and
guava was recorded with cowpea followed by frenchbean intercropping as
compared to plants without intercropping.
Jain et al. (2008) investigated that intercropping in young mango orchard under the watershed of Kymore plateau of Madhya Pradesh of 7 years old mango cv. Totapuri and Banganapalli in between the interspaces of 8m x8m, maximum number of panicles found with intercrop pigeon pea followed by blackgram, maize, ginger and paddy. The maximum number of fruits per plant was found significantly higher from the treatment maize followed by blackgram, pigeonpea, paddy and ginger. The pooled mean of fruit yield of mango was maximum from blackgram and was at par with pigeonpea.

Kumar et al. (2008) conducted field experiment during 2003–04 and 2004–05 to assess the effect of different types of organic mulches on growth, yield and soil moisture in turmeric grown as intercrop in mango orchard under rainfed conditions in Central Horticultural Experiment Station, Bhubaneswar, Odisha. Five treatments paddy straw mulch (1 kg/m²), paddy straw mulch (0.5 kg per m²), local grass mulch (1 kg per m²), local grass mulch (0.5 kg per m²) and control (no mulching) were replicated four times in a randomized block design. Plots of 50m² (5m × 10m size) were prepared in the inter space of mango plantation for space utilization. Results indicated that maximum turmeric plant height (104.65 cm), stem girth (8.95 cm), leaf size (35.92 cm × 15.88 cm), dry biomass (20.90 quintal per hectare), dry root weight (5.08 g per plant), number of finger (10.25), finger weight (156.45 g), mother rhizome weight (60.45 g) and fresh yield (78.65 quintal per hectare) were recorded with the application of paddy straw mulch @ 1 kg per m². Soil moisture content was higher during rhizome formation, development and maturation stage in plots where paddy straw was applied @1kg per m² (1 tonne per hectare). Average maximum yield of mango (5.5 tonnes per hectare) was recorded in control plots (without intercrop) which were at par with other treatments.
Pandey et al. (2008) studied on judicious utilization of inter-spaces in young orchards is a way of improving income of growers in the initial years of orchard establishment. At the Central Horticultural Experiment Station, Bhubaneswar, long term experiments on intercropping of vegetables were conducted in growing young mango (cv. Amrapali and Mallika) orchards. During winter season economic yield of 145.83 quintal, 24.58 quintal, 48.4 quintal, 54.7 quintal, 20.0 quintal and 22.65 quintal with corresponding fresh biomass yield of 51.95 quintal, 75.3 quintal, 88.6 quintal, 54.7 quintal, 224.0 quintal and 140.9 quintal as well as dry biomass yield of 20.78 quintal, 20.8 quintal, 4.3 quintal, 50.9 quintal and 49.9 quintal per hectare, respectively was recorded in tomato, chilli, frenchbean, amaranthus, cow pea and dolichosbean. During summer season maximum economic yield was observed in cow pea (62.5 quintal per hectare) followed by bottle gourd (62 quintal per hectare). Fresh biomass and dry biomass was maximum in cow pea (26,036 quintal per hectare). Fruit yield of mango at 10 years of age was maximum (70kg per tree) in control plots (mango only). Among vegetable crop sequences, maximum fruit yield was recorded in cluster bean- chili-bottle gourd crop sequence (67.5kg per hectare). Soil fertility due to intercropping improved in successive years. Maximum available N in 10 year old mango orchard after 4 years of intercropping was recorded due to cluster bean-chilli- bottle gourd cropping sequence (293.5kg per hectare) as against 222.9kg in control. Maximum available P₂O₅ (61 kg per hectare) and available K₂O (414 kg) in soil was also recorded due to cluster bean-chilli-bottle gourd cropping sequence. In control blocks the available P₂O₅ (37 kg per hectare) and K₂O (208 kg per hectare) remained lower than intercropped blocks.
Rath and Swain (2008) conducted investigation during 2005-06 and 2006-07 in a six years old existing bearing mango orchard (cv. Totapuri) along with five years old filler plant guava (cv. Allahabad Safeda) various intercrops like mango ginger, turmeric, cowpea, French bean, niger, paddy were taken as treatments in mango orchard along with control, a treatment without intercropping at Odisha. Among different intercropping systems tried, the mango + guava + cowpea system resulted maximum improvement in bulk density (1.27 and 1.29 g per cc), water holding capacity (36.60 and 32.30%), organic carbon content (0.7 and 0.63%) and pH (6.74 and 6.70 within 0-15 cm and 15-30 cm of soil depths, respectively. The nutrient status of orchard soil indicated that the mango+ guava + cowpea system also recorded significantly maximum available N, P_2O_5 and K_2O content of 356.7 kg per hectare, 18.9 kg per hectare and 380.7 kg per hectare within 0-15 cm and 317.3 kg per hectare, 16.9 kg per hectare and 345.3 kg per hectare within 15-30 cm soil depths. It was interesting to record that there was significant increase in average fruit weight and fruit yield of 304.6 g and 34.1 kg per tree of mango (main crop) and 102.75 g and 31.90 kg per hectare in guava (filler crop), respectively under mango + guava + cowpea system as compared to control i.e. mango + guava system without intercropping where the corresponding values are 265.30 kg and 22.40 kg per tree in mango and 91.30 kg and 20.30 kg per tree in guava. Economics of the intercropping systems, mango + guava + turmeric recorded the maximum net return, whereas mango + guava+ cowpea combination resulted highest benefit cost ratio.

Sahoo et al. (2008) studied the objective of identification of suitable vegetable as intercrop in pre-bearing drip irrigated mango orchard under western central table land zone of Odisha in sandy loam soils low in organic
matter. Highest yield was recorded in onion (15.8 tonnes per hectare) followed by cabbage (15.5 tonnes per hectare) and radish (13.6 tonnes per hectare). Maximum net return were obtained in onion (Rs.63,300.00 per hectare) followed by radish (Rs.20,500.00 per hectare) and chilli (Rs.19,750.00 per hectare). More benefit cost ratio was observed in onion (3.00) followed by radish (2.51) and chilli (2.17). Hence, onion, radish and chilli vegetables were found more remunerative intercrops in pre-bearing drip irrigated mango orchards of three year old under sandy loam to gravelly soils located at western central table land of Odisha.

Anwer et al. (2011) reported the intercropping of seed spices like fennel, coriander, ajwain and fenugreek in mango orchard at National Research Centre on Seed Spices, Ajmer. Mango orchards offer greater opportunity to increase area under seed spices through inclusion of some seed spices. The coriander and fenugreek are grown in mango orchards only for leafy purpose but not for seed spices. The seed spices like coriander, fennel, fenugreek, ajwain and nigella can very well be tried for intercropping with mango orchard. Hence, during rabi season, inclusion of seed spices as intercropping in mango orchards may be more beneficial for enhancing income of mango growers. Development of mango based intercropping with seed spices is the need of hour to increase production of seed spices in our country along with increasing income of mango growers.

Singh (2011) investigated the effects of intercrops on the yield of mango (cv. Dashehari) with an aim to maximize the production potential and economic returns from mango based intercropping systems (mono and companion) at Central Institute for Subtropical Horticulture, Lucknow. Brinjal as an intercrop in mango orchard recorded the highest yield 19.38
tonnes per hectare followed by bottle gourd 13.54 tonnes per hectare which was significantly superior in terms of production than the other intercropping system. The lowest yield 8.5 tonnes per hectare was recorded with cabbage as an intercrop. Intercropping of brinjal also proved beneficial for increasing the yield 4.55 tonnes per hectare of mango by 8.57% compared to control. The highest monetary return Rs.1,60,300.00 per hectare with brinjal in mango was obtained as compared to Rs. 49,920.00 per hectare in sole crop.

2.2 Intercropping in other fruit crops

Grewal (1960) reported that cluster bean, peas, sengi and wheat as intercrops in Malta orange resulted in the incidence of chlorosis which was observed in the order of wheat > sengi > peas > cluster bean. However, leguminous crops increased girth, height and spread of the trees in Chandigarh, Punjab condition.

Nair et al. (1974) studied on the basis resource of crop production namely soil and solar energy were not being utilized to the maximum extent possible in pure stand crop of coconut. Except during period between 8-20 years of age coconut plantation, interspaces received filtered sunlight varying amount, which might be adequate energy to raise various crops.

Leela and Bhaskaran (1980) studied the groundnut as intercrop in coconut orchard. Spread habit of groundnut significantly suppresses the weed growth and reduced the splash soil erosion in coconut orchard.

Adeyemi (1998) studied the effects of intercropping cashew with maize, cassava, cowpea and plantain within the first 3 years of establishment
in Ibeku, Umuahia, Nigeria. Weed suppression was better in intercropped plots than cashew alone. Consequently, number of weeding per annum and weed dry weight in intercropped plots were lower than those of cashew grown alone.

Badshah et al. (2000) reported that soybeans, berseem and wheat were grown as intercrops in a peach orchard to determine their effects on the vegetative growth, quality of fruit and yield of peach. The highest shoot length (62.85 cm), maximum number of flowers per limb (10.22) and maximum number of fruit per limb (5.82) were found from soyabean interculture compared with 52.42, 9.62 and 4.17 fruit set in controls and maximum yield (38.7 kg per tree) was also observed in soyabean interculture followed by berseem intercropping (30.9 kg per tree) as compared with 15.25 kg per tree in controls and 10.04 kg per tree in wheat inter culture respectively.

Awasthi et al. (2002) also reported that intercropping leguminous vegetables (French bean, cowpea and fenugreek) with different papaya cultivars (Farm selection, Pusa delicious, Coimbatore-2 and Honey Dew). There was no perceptible deleterious effect on the productivity of papaya cultivars due to intercropping of vegetable crops.

Lenka et al. (2005) studied on feasibility and profitability of intercropping with groundnut, cowpea, turmeric, and pineapple in cashew, which was taken under Odisha condition. The results revealed that these were grown successfully as intercrops in 9-10 year old cashew orchards without affecting the yield of main crop. The net profit ranging from Rs.5,060.00 per hectare in cashew + groundnut crop combination to
Rs.30,150.00 per hectare in cashew + turmeric crop combination could be obtained. In view of the low investment and better profitability as well as maintaining the soil fertility, cowpea intercropping in cashew orchard recorded highest cost benefit ratio (1:4.84).

Mitra et al. (2006) concluded that in the young guava plantation of 275 plants per hectare in West Bengal during the first year after planting several intercrops in the rainy season amorphophallus, colocasia, brinjal, coriander leaf and in winter season cabbage, pumpkin, bitter gourd are grown and earned about Rs.15,000.00 to 20,000.00 per hectare. Further, from 3rd year onward, a net profit of Rs.25,000.00 per hectare is very common from guava orchards under the West Bengal condition and most prefer winter crop as intercrop.

Ram and Pathak (2007) pointed out that the maximum fruit number and yield of guava plant cv. Allahabad Safeda were recorded constantly for 2 years in trees, supplied with 20kg farm yard manure and inoculated with Azotobactor.

2.3 Turmeric as intercrop in other fruit crops

Jaswal et al. (1993) studied the performance of two rhizomatous crops i.e. ginger and turmeric under rainfed conditions in pure stands and as intercrops with 5-year-old poplars planted at three spacing, 5m×5 m, 5m×4m and 5m ×3m. The study was carried out at the experimental farm of Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, Himanchal Pradesh. The soil is sandy loam with pH 7.8. The average illumination below the canopies was 53, 46 and 38% of incident radiation, respectively. Both crops performed better as intercrops than as pure stands. Survival was inversely correlated to
light intensity. Plant height, tillers per plant and leaves per plant in ginger and leaf length and leaf breadth besides plant height in turmeric were significantly enhanced when intercropped. The rhizome length, rhizome breadth, yield per plant and yield per hectare in ginger exceeded under poplars but showed a drastic reduction under the closest poplar spacing. In turmeric, the trend for the first two characters was the same, whereas yield per plant as well as yield per hectare were slightly greater in the open than under 5m×3m spacing. Dry matter content varied significantly with spacing. For quality parameters, only oil content in ginger and oleoresin in turmeric showed significant differences. The cultivation of turmeric proved more remunerative than ginger.

Usha (2011) reported turmeric as intercrop can find application in organic farming systems, to control various soil borne pests and diseases in several fruit orchards and thereby boosts mango yield. Turmeric can be grown as an intercrop with many other fruit crops because it comes up well in partial shade conditions, although thick shade affects the yield adversely. These plants are generally hardy in nature and have shorter economic life than the main crops.

2.4 Ginger as intercrop in other fruit crops

Sharma et al. (1996) conducted a trial, in a 30 years old coconut stand which were spaced at 7.5mx7.5m under rainfed conditions and found that coconuts yield were increased by all the three intercrops colocasia, ginger and turmeric, however with colocasia resulting in the greatest 10.61% more than monocrop.
Hore et al. (2004) carried out field experiments to study the effect of different spacing (20 × 15 cm, 20 × 20 cm and 25 × 20 cm) and potassium levels (100, 150 and 200 kg per hectare) on ginger cv. Gurubathan, intercropped in 1 year old arecanut cv. Mohitnagar plantation and to the ultimate effect of intercrops on the growth of the main crops. The experiment was carried out at BCKV, Nadia, West Bengal. The data revealed that narrow spacing produced taller plants (90.13 cm), while widest spacing recorded higher number of tiller (15.04) and leaves (221.18). Among the potassium levels, the medium dose (150 kg per hectare) was found better for maximum growth and yield attributes. The maximum weight of clump was recorded under medium spacing. The highest projected yield (13.69 tonnes per hectare) was recorded with the combination of closer spacing (20 cm x 15 cm) with medium dose of potassium (150 kg per hectare). The beneficial effects of intercrops on growth parameters of arecanut were also observed.

2.5 Pineapple as intercrop in other fruit crops

Effect of intercropping in pineapple was studied by Radha et al. (1991). Pineapple cv. Kew was grown at a spacing of 30 cm x 60 cm x 180 cm and intercropped with ginger, turmeric, cowpea, colocasia and at spacing of 30 cm x 60 cm x 90 cm as monocrop. It was observed that the yield was significantly higher when pineapple was raised as monocrop at higher density, than when intercropped with other crops at lower density.

Salam (2001) studied the crop association involving cashew and pineapple, which proved as an excellent combination to the agro-ecological condition that prevails in that area. It yields all the agronomic advantages in terms of sharing of nutrients, smothering of weeds, conservation of soil and water enhanced growth for cashew. It also provides good returns to the farmer.
2.6 Integrated nutrient management in mango

Silva and Siqueira (1991) observed the effect of 6 vesicular-arbuscular mycorrhizal fungi, inoculated singly or in combination on initial growth and nutrient contents of mango seedling and some other fruit crops under greenhouse condition in a soil vermiculate mix amended or un-amended with soluble superphosphate. They found that mango seedlings had a better growth response only when inoculated with *Glomus margarita* and mixed inoculums in soluble superphosphate amended soil.

Sivakumar (2001) studied that the effect of biofertilizers on the growth of mango rootstocks in an experiment conducted in Paiyur, Tamil Nadu. Treatments comprised of i) *Azospirillium* at 400g, ii) *Phosphobacteria* at 400g, iii) *Azospirillium* at 400g + *phosphobacteria* at 400g and iv) inoculated control. All treatments were superior to control but *Azospirillium* at 400g + *phosphobacteria* at 400g recorded the highest value for plant height, root length, number of leaves, stem width, root volume and germination increase.

Satapathy (2002) carried out experiment in West Bengal, India during 1999-2000 to evaluate the effect of inorganic fertilizers (N, P$_2$O$_5$, and K$_2$O) on flowering, fruit growth, yield and fruit quality of mango cv. Amrapali. The highest hermaphrodite per male flower ratio was recorded by applying 50 g N and 100 g each of P$_2$O$_5$ and K$_2$O per plant per year. Application of 100 g each of N, P$_2$O$_5$ and K$_2$O per plant per year markedly increased the number of fruits per plant, yield, pulp content and also improved fruit quality.

Ahmad (2004) studied on the effects of N fertilizer and *Azotobactor* on the performance of mango cv. Amrapali in New Delhi, India. Treatment with 145g N per plant and *Azotobactor* CBD-15 gave the greatest increase in shoot
length (25.52%), fruit weight (136.13 g) and beta-carotene content (18.67 mg per 100 g pulp). The highest TSS (23.64%) and ascorbic acid (45.53 mg per 100 g pulp) contents were obtained with 96g N per plant and Azotobacter CBD-15. The highest yield was recorded for 145g N per plant (23.89 kg per plant) and 96 g N per plant (23.74 kg per plant). The results suggested that 96g N per plant in combination with C. chroococcum CBD-15 was optimum for the improvement of the yield and quality of mango under high-density planting.

Gogoi et al. (2004) observed that half recommended dose of N and full dose of phosphorous + Azospirillium + Phosphate solubilizing bacteria significantly increased in banana yield and harvest index.

Ghosh (2004) conducted experiment in West Bengal, India, to determine the effect of organic and inorganic fertilizers on the growth, yield and physicochemical properties of mango cv. Himsagar. The treatments comprised of N at 200, 300 and 400 g, P$_2$O$_5$ at 100, 200 and 300 g, K$_2$O at 100, 200 and 300 g and 40 kg organic manure all applied per plant per year. Data were recorded for N, P$_2$O$_5$ and K$_2$O contents in the leaves, fruit yield per tree, fruit weight and contents of total soluble solids, total sugar and ascorbic acid. Tree height and basal girth was highest with N 300g, P$_2$O$_5$ 200g, K$_2$O 200g and organic matter.

Ahmad (2004) carried out experiments during 1996 and 1997, in New Delhi, India, to evaluate the effects of different doses of N fertilizer (1/3, 2/3 and full dose of N, i.e. 145 g urea per tree), with or without biofertilizer (Azotobactor), on the nutrient uptake of 10-year-old Amrapali mango grafted on Kurukkan rootstock at a distance of 3mx3m (1600 plants per hectare). All plots received a single dose of P$_2$O$_5$ (335 g per tree) and K$_2$O (420 g per tree) in the form of single superphosphate and muriate of potash respectively. Leaf N
content in all treatments increased after the fruit harvest in July with the application of higher doses of urea, whether applied singly or in combination with Azotobactor. T2 showed the highest uptake of N at flowering and after harvest, followed by treatments 7 and 8 (both with Azotobactor only). It clearly indicates that the Azotobactor as a biofertilizer compensates for the absence of N fertilizer in mango. All treatments increased leaf P2O5 content over the control, with the highest being observed in T1, T2 and T6. Azotobactor application favoured P2O5 uptake. Leaf K2O content was generally higher after harvest than at flowering, with the highest values being observed in T4 and T2. Leaf P2O5 content was relatively higher with the application of Azotobactor. Micronutrients (e.g. Cu and Zn) increased at flowering and after harvest irrespective of the treatments, but T1 and T4 showed comparatively higher values, indicating Azotobactor have equally effective for the uptake of both micronutrients.

Estrada (2004) studied the effect of the application of the biofertilizer Maya Magic, clearing and bagging on some quality characteristics of mango cv. Kent at fruit set, leaving one or two fruits per panicle, performing four to five intermittent shakings per branch and eliminating the fruitless inflorescence axes. The results indicated significant difference between treatments, fruits with Maya Magic, registered the highest TSS content 10.4 ° brix, the highest resistant to penetration 8.3 pounds occurred with more bagging and the highest weight per fruit 452 g was obtained when applying Maya Magic and leaving one fruit per panicle, whereas the lowest weight 397g per fruit was registered the conventional control. It was observed that with a timely elimination of the rachis, did not fasten flowers or fruits, more weight was accumulated on the harvested fruit.
Chen et al. (2005) obtained that phosphate solubilizing activity was associated with the release of organic acid and a drop in the pH of the medium and increased the yield of the crop by converting insoluble forms of phosphorous to as accessible form.

Patel et al. (2005) carried out studies in mango cv. Amrapali using farmyard manure at 50 and 100kg per plant, vermicompost at 16.5 and 33kg per plant, *Azotobactor, Azospirillum*, mixed strain of arbuscular mycorrhizal fungi and phosphate solubilizing bacteria. All the biofertilizers were applied at 10g per plant, while the arbuscular mycorrhizal fungi at 20g per plant. The highest number of fruits 195.2, fruit weight 170.5g per fruits, TSS 20.8%, beta-carotene 15,900 iu per 100g and ascorbic acid 36mg per 100g were recorded with FYM 50kg + vermicompost 16.5kg + *Azotobactor* 10g and PSB 10g per plant.

Bhargava (2006) reported that the harvest optimum yield, good quality fruits of mango N: P₂O₅: K₂O of 0.80:0.48:1.00 ratio is required as compared to N: P₂O₅: K₂O @ of 7.2:2.66:1.00 being consumed by all the agricultural, horticultural, plantation crops. Further, use of organic manures and biofertilizers increase use efficiency of chemical fertilizer and improve the quality of fruits.

Sujatha et al. (2006) stated that the application of organic and inorganic forms of nutrients N: P₂O₅: K₂O (100:100:100) + 75 kg farm yard manure per tree along with drip irrigation at 0.25, 0.5 and 0.75 Ep increased the fruit number and weight significantly compared to the mango cv. Kesar. However, drip irrigation at 0.75 Ep gave higher fruit yield 44.09kg per tree than control 8.4 kg per tree in alfonsols of semi-arid tropics.
Chowthury and Rahim (2006) studied the effect of fertilizers on the incidence of anthracnose disease, yield and quality of mango. The investigation was carried out at Germplasm Centre (GPC), FTIP, Department of Horticulture, BAU, Mymensingh, Bangladesh. Combined application of N, P$_2$O$_5$, K$_2$O, Zn SO$_4$, gypsum and cow dung gave the highest number of healthy fruits.

Hasan et al. (2009) found that the effect of organic and inorganic nutrient in improving flowering in mango cv. Himsagar. The experiment with different organic and inorganic nutrients was conducted at the Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The highest shoot growth was recorded in the plant receiving 100% recommended dose of fertilizer along with Azospirillium and vesicular arbuscular mycorrhizal inoculation, whereas maximum flowering and fruiting were observed in plants supplied with 50 % recommended dose of nutrients with Azospirillium and vesicular arbuscular mycorrhizal inoculation.

Paulino et al. (2009) studied biological fixation and nitrogen transfer by three legume species in mango and soursop organic orchards in Brazil. Gliricidia showed the highest BNF potential (80%), followed by sunhemp (64.5%) and pigeon pea (45%). After two sunhemp prunes, 149.5 kg per hectare of N per year were supplied. After three annual prunes, gliricidia supplied 56.4 and 80.3 kg per hectare of N per year in two consecutive years. The quantity of N supplied to the system was higher than the mango and soursop requirements. Gliricidia and sunhemp were prominent in N transfer, with approximately 22.5 and 40% respectively. Green manuring using gliricidia permits fractioning of the N supply, which is an advantage in N obtain by the fruit trees.
Trivedy (2010) observed that the treatment of 500:500:500 g N, P₂O₅, K₂O + 30 kg farm yard manure + 250 g *Azospirillium* per tree showed maximum plant height, trunk girth and canopy spread followed by 500:500:500 g N, P₂O₅, K₂O + 30 kg farm yard manure + 250 g *Azotobacter* per tree. With regard to physicochemical properties, again 500:500:500 g N, P₂O₅, K₂O + 30 kg farm yard manure + 250 g *Azospirillium* per tree followed by 500:500:500 g N, P₂O₅, K₂O + 30 kg farm yard manure + 250 g *Azotobacter* per tree in new alluvial zone of West Bengal.

Manna (2011) conducted experiment at the Central Research farm of Regional Research Station, New Alluvial Zone, BCKV, Nadia, West Bengal during the years 2006-2008 to study the effect of organic, inorganic fertilizers, biofertilizers and growth retardant on soil nutrient status of mango orchard. The observations on available nutrient status (N, P₅O₅, K₂O, Zn and B) of the orchard soil were estimated against four different organic manures (green manure, farm yard manure, vermicompost and control) and seven treatments consisting of inorganic nutrients, biofertilizers and growth retardant along with the disease severity of foliar anthracnose, gummosis and mango die back diseases. Application of 850 g N+425 g P₂O₅ +1000 g K₂O + 250 g *Azospirillium* + 250 g phosphate solubilizing bacteria + 100 g Zn SO₄ + 100 g borax per tree per year (T₇) in combination with either green manure or farm yard manure or vermicompost improved the available nutrient content of orchard soil (N, P₂O₅, K₂O, Zn and B) and reduced the incidence of disease severity.

Kumar and Singh (2011) conducted experiment at Horticulture Research Centre, Patherchatta, G. B. Pant University of Agriculture and Technology, Panthnagar during the years 2007-08 and 2008-09. The experiment was conducted on 18 year old mango trees of cv. Dashehari.
Maximum tree height was observed with the application of 25 kg poultry manure per tree during both the years. Tree spread, shoot length, number of fruits per tree and fruit yield per tree were maximum with the application of 75 kg vermicompost per tree during both the years. Physical characteristics like fruit weight, fruit volume, fruit length, fruit breadth, pulp weight, peel weight and stone:pulp: peel ratio of fruit was found maximum in 75 kg poultry manure per tree during both the years. Maximum TSS, titratable acidity, ascorbic acid, TSS: acid ratio and total sugars of fruits were observed with application of 75 kg vermicompost per tree during both the years. Increase in TSS, total sugars, reducing sugars, non-reducing sugars and a-carotene contents were observed from the day of harvest to 6 days of storage then it declined under all the treatments during both the years. The maximum TSS, titratable acidity and ascorbic acid content were recorded from the day of harvest to 8 days of storage with application of 75 kg vermicompost per tree during both the years. The maximum total sugars, reducing sugars and non-reducing sugars contents were maximum between 2 to 8 days of storage in 75 kg poultry manure per tree during both the years. Maximum N content in the leaves was found with application of 30 kg neem cake per tree, while leaf P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O contents were found with application of 75 kg poultry manure per tree.

### 2.7 Integrated nutrient management on other fruit crops

Nath and Haribabu (2007) observed that the vermicompost was superior over the organic sources followed by poultry manure and leaf litter in improving the repetitive growth, flowering, fruiting, yield and fruit quality along with improvement in soil fertility and leaf nutrient status of the guava plant.
Ansari and Hazarika (2009) found that the integrated use of organic and 100 % recommended dose of N: P₂O₅: K₂O along with biofertilizers increased N: P₂O₅: K₂O concentration in plant and soil after harvest in banana.

Bhalerao et al.(2009) performed studies on integrated nutrient management for tissue culture Grand Naine banana at Banana Research Station, Jalgaon, India. Application of 100% recommended dose of N: P₂O₅: K₂O with 10 kg farm yard manure per plant and biofertilizers (Azospirillium and phosphorous solubilizing bacteria @ 25 g per plant each) were found beneficial in terms of banana yield and monetary return.

Shukla et al.(2009) in guava reported that the application of 50% dose of N:P₂O₅:K₂O + 50g Azotobacter significantly increased the canopy volume (201.43m³), fruit weight (153.30g), TSS (14°Brix), ascorbic acid (198.30 mg per 100g pulp), reducing sugar (4.77%) and total sugar (8.10%) in cv. Sardar guava.

Dutta et al. (2009) worked on guava in Nadia, West Bengal, India recorded Azospirillium + VAM inoculation along with 100% N and 100% P₂O₅ showed effective in increasing the TSS, total sugar and ascorbic acid content of fruits.

Singh and Singh (2009) stated that integrated nutrient management consisting of Azotobacter + Azospirillium+ 60 kg N per hectare+ 100 ppm GA₃ was recorded highest chlorophyll content in leaves, highest fruit set, yield, fruit quality and improvement in the plant nutrient status in strawberry cv. Sweet Charlie.
Dutta et al. (2010) studied the integrated nutrient management in Litchi cv. Bombai in new alluvial zone of West Bengal. The study with organic manures and biofertilizers with or without chemical fertilizers combinations was conducted on litchi cv. Bombai. Results revealed that different combinations involving the use of organic nutrition to reduce the chemical fertilizers and had significant effect on yield, fruit quality and leaf mineral content. The treatment consisting of 50 kg per tree farm yard manure+150 g *Azotobactor*+100 g vesicular arbuscular mycorrhizal + 500 g N: 250 g P$_2$O$_5$: 500 g K$_2$O per tree per year showed maximum yield (98.72 kg per plant) and also have a significant improvement in terms of TSS, total sugars, ascorbic acid, TSS: acid ratio, fruit weight and fruit size. Treatment with only organic manure and biofertilizers also resulted in improvement in fruit quality over application of only chemical fertilizer but had less effect on productivity.

### 2.8 Integrated nutrient management in turmeric

Medda and Hore (2003) conducted experiment at on turmeric cv. *Suguna* with levels of N (100, 150 and 200 kg per hectare) and K$_2$O (100, 150 and 200 kg per hectare) along with uniform dose of P$_2$O$_5$ @ 60 kg per hectare. The maximum plant height, leaf number and leaf dimension were obtained with highest level of both N and K$_2$O (N 200 K$_2$O 200). The same combination of nutrient also showed pronounced effect on weight of clumps, i.e. yield per plant, weight of primary fingers and yield per hectare. Maximum number of primary fingers and secondary fingers were observed in N 150, K$_2$O 200 and N 200, K$_2$O 100 kg per hectare treatment respectively, while both longest primary and secondary fingers were recorded in N150, K$_2$O 200 kg per hectare. Application of 200 kg N, 60 kg P$_2$O$_5$ and 200 kg K$_2$O per hectare may be adopted for obtaining higher yield of turmeric in alluvial plains of West Bengal.
Sanwa et al. (2007) carried out experiment to study the effect of various organic manures on yield and quality parameters of turmeric and their effect on residual soil fertility. The results showed that significantly higher rhizome yield was recorded with the application of farm yard manure @ 18 tonnes per hectare which was statistically at par with 10 tonnes per hectare poultry manure. Application of various organic sources resulted higher rhizome yield over control and also improved the quality parameters. Organic manuring not only produced the highest and sustainable crop yields but also improved the soil fertility and productivity.

Jadhao et al. (2008) conducted an experiment during kharif season of 2005 to 2007 at to standardize the suitable dose of organic manure for better production and quality of turmeric. Different organic manures were applied (200 + 100 +100 kg N: P$_2$O$_5$: K$_2$O per hectare, neem cake 4 tonnes per hectare, safflower cake 4 tonnes per hectare, vermicompost 13.5 tonnes per hectare, farm yard manure 20 tonnes per hectare, poultry manure 13.5 tonnes per hectare, sheep and goat manure 201 tonnes per hectare, castor cake 4.61 tonnes per hectare, fish meal 2.85 tonnes per hectare, control) to the turmeric crop by compensating the quantity of recommended dose of nitrogen and compared with the recommended dose of N: P$_2$O$_5$: K$_2$O. The significant results were found in respect of growth on yield attributing characters. Turmeric growth performance in respect of plant height, leaf area, number of leaves and stem girth were significantly superior in the treatment vermicompost @ 13.5 tonnes per hectare. As regard to the different yield attributing application, farm yard manure @ 20 tonnes per hectare exhibited significantly superior performance in all characters, being maximum in number, weight and size of mother rhizome and fresh finger. This performance was
followed by the treatment vermicompost @ 13.5 tonnes per hectare. The yield of turmeric as regards mother rhizome, was significantly maximum in the treatment farm yard manure @ 201 tonnes per hectare followed by vermicompost @ 13.51 tonnes per hectare.

Mannikeri et al. (2008) observed that under Karnataka condition application of vermicompost @ 15.65 tonnes per hectare recorded significantly the highest plant height (35.80 cm), number of leaves (8.93), number of tillers (3.17), leaf area (47.87 cm²) and leaf area index (0.473) and was on par with the application of press mud @ 15 tonnes per hectare (34.55 cm, 8.35, 3.15, 44.09 cm² and 0.429, respectively for plant height, number of leaves, number of tillers, leaf area and leaf area index). While, the application of (180:90:90 kg N: P₂O₅: K₂O per hectare) recorded the values of 31.64 cm, 7.75, 2.60, 39.95 cm² and 0.395, respectively for plant height, number of leaves, number of tillers, leaf area and leaf area index. Application of vermicompost recorded significantly the highest fresh and cured rhizome yield (33.62 and 6.74 tonnes per hectare, respectively) and was at par with press mud (29, 48 and 5.59 tonnes per hectare, respectively). While the application of recommended dose of fertilizer recorded 22.80 and 4.59 tonnes per hectare, respectively for fresh and cured rhizome yield.

Gill et al. (2008) found that mulching had significant influence on growth and yield of turmeric. N at 150 kg per hectare and K₂O at 160 kg per hectare had significantly better independent effect on almost all the parameters. The chlorophyll content of leaves and foliar nutrient composition also differed significantly with the treatments. However, the highest yield and curcumin content were noted with a combination of mulching + application of N and K₂O at 120 and 160 kg per hectare.
Dinesh et al. (2010) carried out an experiment at Division of Crop Production and Post-Harvest Technology, Indian Institute of Spices Research (IISR), Kerla and found that application of organic manures and biofertilizers positively influenced microbial biomass C, N mineralization, soil respiration and enzymes activities. Contrarily, greater metabolic quotient levels indicated a stressed soil microbial community. Principal component analysis indicated the strong relationship between microbial activity and the availability of easily mineralizable organic matter. Findings imply that even short-term incorporation of organic manures and biofertilizers promoted soil microbial and enzyme activities and these parameters are sensitive enough to detect changes in soil quality due to short-term incorporation of biological fertilizers.

Singh and Dixit (2010) conducted experiments during kharif 2004 and 2005 on turmeric cv. T-12 at acid alfisol of Himachal Pradesh on silty clay loam soil with eleven treatments including a control. The pooled results of two year indicated that maximum curcumin (3.31%) and oil content (2.85%) were found in the treatment 100% N: P2O5: K2O + 20 tonnes farm yard manure per hectare as soil mulch. Whereas starch (8.11%), protein (4.92%) and curing percentage (21.53%) were found highest at 100% N:P2O5:K2O+ 20tonnes farm yard manure per hectare as soil incorporation.

Roy and Hore (2011) carried out an experiment with two biofertilizers (Azospirillum and Arbuscular mycorrhizal fungi and four organic manures, compost, vermicompost, phosphor compost and mustard cake) in comparison with inorganic management at Horticultural Research Station, Mondouri, BCKV, West Bengal to identify the suitable bio-organic combination for production of organic turmeric cv. Suguna grown as intercrop in six years old
arecanut cv. Mohitnagar plantation. The plants grown under bio-organic management exhibited better growth and yield as compared to inorganic management. The maximum projected yield (28.94 tonnes per hectare) was observed with vermicompost + *Azospirillium* + *Arbuscular mycorrhizal* followed by compost + *Azospirillium* + *Arbuscular mycorrhizal* (26.93 tonnes per hectare) as compared to 24.11 tonnes per hectare under inorganic management. Economic assessment of different treatments revealed that maximum return was realized from vermicompost + *Azospirillium* + *Arbuscular mycorrhizal* (Rs. 1,79,712.00) followed by compost + *Azospirillium* + *Arbuscular mycorrhizal* (Rs. 1,64,571.00) as compared to Rs. 93,808.00 under inorganic management. The benefit cost ratio of the above three treatments were 1.86, 1.89 and 1.14, respectively.

### 2.9 Integrated nutrient management in ginger

Nath and Korla (2000) conducted experiment at Department of Vegetable Crops, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, reported that the biofertilizer treatments gave better results in respect of plant stand, plant height, number of tillers and leaves per plant over normal dose of N: P\textsubscript{2}O\textsubscript{5}: K\textsubscript{2}O and control. The *Azofert* biofertilizer, irrespective of application were found to be most effective for growth and development. *Azofert* was efficient over Natrin, N: P\textsubscript{2}O\textsubscript{5}: K\textsubscript{2}O application and no biofertilizers for increasing the size of rhizome and yield. The net returns and benefit: cost ratio was also maximum with *Azofert* treatment.

Dashet *et al.* (2008) conducted experiment in AICRP on Spices, HARS (O.U.A.T) Koraput, Odisha in ginger cv. Suprabha seed treatment with both *Trichoderma harzianum* and *Pseudomonas inflorescence* + soil drenching with both *Trichoderma harzianum* and *Pseudomonas inflorescence* absolute control. The recommended method and dose of seed treatment and soil drenching are
followed in each of the experiment plot of size 3m². Among the treatment combination T6 (Seed treatment with both *Trichoderma harzianum* and *Pseudomonas inflorescence* and soil drenching with both *Trichoderma harzianum* and *Pseudomonas inflorescence* recorded highest sprouting percentage of 96.0 % followed by seed treatment with *Trichoderma harzianum* and *Pseudomonas inflorescence* of 92.0 % and seed treatment with *Trichoderma harzianum* + soil drenching with *Trichoderma harzianum* 91.0%. Seed treatment with both *Trichoderma harzianum* and *Pseudomonas inflorescence* and soil drenching with both *Trichoderma harzianum* and *Pseudomonas inflorescence*) recorded highest sprouting percentage and yield with least disease infestation.

Rana and Korla (2010) conducted experiment at Department of Vegetable Crops, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan and assessed the effect of organic manure and inorganic fertilizer on yield and quality of ginger. Highest rhizome yield (11.59 tonnes per hectare) was recorded with *Azospirillium* alone in comparison to inorganic fertilizers although the differences were non-significant.