

## REVIEW OF LITERATURE

The cole crops, viz., cabbage (*B.oleracea var. capitata*), cauliflower (*B. oleracea var. botrytis*), broccoli (*B. oleracea var. italica*) and knol khol, (*B. oleracea var. gongylodes*), constitute an important group of vegetable crops in India. These crops, requiring a cool and moist climate for their growth and development, are basically temperate or winter season crops, but cauliflower and cabbage are also grown quite extensively in other seasons under the cool climate of high hills of North and South India. The cole crops can be grown on a wide range of soils, starting from sandy loam to clayey soils, but heavy soils such as silt loam and clay loam with high organic matter content are preferred for higher productivity. The optimum soil pH is 6-7 for cauliflower and 5.5-6.5 for cabbage, broccoli and knol khol. The cole crops are heavy feeders requiring large quantities of manures and fertilizers.

### 2.1 NPK REQUIREMENTS OF COLE CROPS

Khurana *et al.* (1990) conducted a trial on cauliflower, cv. Punjab giant-26 with nitrogen at 0,90,120 and 150 kg N/ha and P<sub>2</sub>O<sub>5</sub> at 0,40 and 60 kg/ha with K<sub>2</sub>O at 60 kg/ha. Application of 120 kg N and 40 kg P<sub>2</sub>O<sub>5</sub> along with 60 kg K<sub>2</sub>O per hectare gave good yield.

Thakur *et al.* (1991) worked on the effects of 5 rates of N application (80,120,160,200 and 240 kg/ha), 4 rates of P application (100,150,200 and 250kg/ha) and 2 rates of K application (0 and 20 kg/ha) on cauliflower cv. Pusa snowball-1. They observed that increasing rate of nitrogen delayed curd maturity, increased dry matter content, gross plant height, stalk length, number of leaves per plant, leaf area and curd yield (507.09 and 705.05 g/plant with 80 and 240 kg/ha respectively).Increasing rate of

P application hastened curd maturity, reduced stalk length, leaf size and stalk rot and increased gross plant weight, number of leaves /plant, dry matter content and curd yield.

Singh and Naik (1993) evaluated four rates of N application (50,100,150 and 200 kg/ha) and 3 rates of P<sub>2</sub>O<sub>5</sub> (50,100 and 150 kg/ha) application in cauliflower cv. Early Kunwari. All the P and half N were applied at planting ; the remaining N was applied 30 days later. N at 200kg/ha and P at 100 kg/ha gave the highest average curd size, weight and yield.

Balyan and Singh (1994) studied the effects of N (0,40,80,120 and 160kg/ha), P<sub>2</sub>O<sub>5</sub> (0 and 50kg/ha) and Zn (0,10,20 and 30kg ZnSO<sub>4</sub>/ha) on the yield of cauliflower cv. Snowball-16. The highest yield (234.4 q/ha) was obtained at 120kg N/ha, 50 kg P<sub>2</sub>O<sub>5</sub>/ha and 20 kg ZnSO<sub>4</sub>/ha.

Bracy *et al.* (1995) conducted a trial on direct sown broccoli cv Early dawn. The effects of pre-sowing application of NPK fertilizer at rate of 45 kg N + 59 kg P + 112 kg K and 90 kg N + 118 kg P + 224 kg K/ha plus side dressed N fertilizer at 134,196 and 250 kg/ha either dropped onto or knifed into the bed were determined. The marketable yield, early yield, head weight and percentage of early to total yield remained unaffected by fertilizer rate or method of application.

Lisiewska and Kmiecik (1996) working on broccoli cv. Corvet F1 and cauliflower cv. Sernio RS found that broccoli contained 116.3-116.4 mg Vitamin C (ascorbic acid) and cauliflower contained 60.5 – 64.7 mg vitamin C in 100g of fresh matter with application of 80 kg N/ha. Increasing nitrogen application from 80 kg to 120 kg N/ha decreased vitamin C content in cauliflower by 7% and increased nitrates content 44% in broccoli and by 33% in cauliflower.

Everaarts *et al.* (1997) worked on broccoli and found that row application of nitrogen was superior to broadcasting and that a single dose of 260 kg N/ha (minus the amount of mineral nitrogen present in the top 60 cm layer of soil) applied in rows at the time of planting was the best. A high yielding crop takes up 200-250 kg N, 50 kg P and 350 kg K/ha.

Wang *et al.* (1997) worked on the effects of N,P and K on yield and quality in broccoli. Potash (K) was found to be the most important nutrient for yield and dry weight. Application of N + P gave 110.8% higher yield than N alone. When K was applied with N+P, additive effects were observed on yield and source-sink vitamin C (ascorbic acid) content. They concluded that balanced application of N,P and K would give high yield and good quality.

Balyan *et al.* (1998) applied different doses of fertilizers – N at 0 – 160 kg/ha, P<sub>2</sub>O<sub>5</sub> at 0 – 50 kg/ha and ZnSO<sub>4</sub> at 0 – 30 kg/ha in cauliflower. P<sub>2</sub>O<sub>5</sub> and ZnSO<sub>4</sub> and one third of N were applied before transplanting and the remaining N was top-dressed at 30 and 45 days after transplanting. Maximum yield of 238 q/ha was obtained with 160 kg N + 50 kg P<sub>2</sub>O<sub>5</sub> + 20 kg ZnSO<sub>4</sub>/ha.

Sharma and Sharma (1999) recommended a combination of 90kg N and 60 kg P<sub>2</sub>O<sub>5</sub> per hectare. Which give the highest economic returns in terms of head yield in broccoli.

Everaats *et al.* (1999) studied the effect of rate and method of nitrogen application on yield and quality of broccoli cv. Emperor for three seasons. Different amounts of N fertilizer were applied as broadcasting and band placed at planting. Application of nitrogen gave larger heads.

Sanderson and Ivany (1999) studied the efficacy application methods (broadcast, split-broadcast + side dress and banded) at two rates of N (120 & 90 kg/ha) plus a control of 150 kg N/ha applied by broadcasting in three Cole

crops. Marketable yield of cauliflower, cabbage and broccoli was lower by 6-21, 14-33 and 2-26 % respectively, with the reduced nitrogen rates compared to the control. Banded application gave less yield in cabbage and broccoli. The lower N rate gave the lowest yield in all the crops.

Swaroop *et al.* (1999) studied the effect of combinations of 3 levels of nitrogen (45,90 and 135 kg n /ha) and 3 levels of Phosphorous (40,80 and 120 kg P<sub>2</sub>O<sub>5</sub>/ha) on cauliflower cv. Best early. The maximum average weight of curd (408.5g), diameter (12.84 cm) and curd yield (64.85 q/ha) were recorded at 90 kg N and 80 kg P<sub>2</sub>O<sub>5</sub>/ha. Application of N at 135 kg/ha and P<sub>2</sub>O<sub>5</sub> at 120kg/ha resulted in significant decreased in yield components.

Everaarts *et al.* (2000) studied the effect of the rate of nitrogen uptake and utilization by broccoli. Maximum uptake of nitrogen was 300 kg/ha. Nitrogen application resulted in a higher head dry matter production, but the efficiency of nitrogen utilization for the production of head dry matter decreased with higher amounts of nitrogen application.

Jana and Mukhopadhyay (2001) studied the effect of N (0,50,100 and 150 kg/ha) and P (0,40,80 and 120 kg/ha) on yield components of cauliflower cv. Aghani was conducted at Nadia, West Bengal. The increase in nitrogen levels up to 150 kg/ha increased plant height, leaf length, leaf width, days to curd initiation, days to curd maturity, curd diameter, curd depth, net curd weight and marketable curd yield. Phosphorous level up to 120 kg/ha increased plant height, leaf length, number of leaves/plant, net curd weight and marketable curd yield significantly over its lower levels. Leaf width, curd diameter, curd depth and curd solidity at 120 kg P<sub>2</sub>O<sub>5</sub> per hectare were statistically at par with that of 80 kg P<sub>2</sub>O<sub>5</sub>/ha. The application of 150 kg N/ha and 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded the highest value with respect to number of leaves/plant, curd diameter, curd depth, net curd weight, curd solidity,

marketable curd yield and net returns(Rs 37285/ha) and improves the benefit cost ratio (3.25:1) than other treatment combinations.

Mourao *et al.* (2001) observed that application ammonium nitrate as top dressing at 5 rates (0,60,120,180 and 240 kg N/ha) increased the fresh shoot length with increasing nitrogen up to 180 kg N/ha.

Karitonas *et al.* (2001) studied the effect of rates of nitrogen application (6 – 130 kg N/ha) on yield and quality of broccoli and found that yield was closely related with nitrogen supply at planting. The optimum dose of N was found to be 130 kg/ha.

Brahma *et al.* (2002) studied the effect of combinations of nitrogen, phosphorous and potassium on growth and yield of broccoli, cv. Pusa Broccoli KTS-1 was conducted at Assam Agriculture University, Jorhat. The treatments comprises: 0:0:0, 80:30:20,100:60:40,150:80:60 and 200:120:80 kg NPK/ha. Highest head yield (13.41 t/ha) and highest protein (3.36) and total chlorophyll content of head (0.46 mg/g) were obtained at 200:120:80 kg NPK/ha.

Babik *et al.* (2002) studied the effect of nitrogen application at 100,200,400 and 600 kg N/ha under irrigation on yield and quality of broccoli. Nitrogen at 200,400 and 600 kg N /ha was applied as single pre-planting dose and split application, while 100 kg N/ha was applied as pre-planting dose only. The heads were attractive green at higher dose of nitrogen but there was incidence of hollow stem. Also with high nitrogen, sugar content increased but the level of dietary fiber and ascorbic acid content decreased.

Singh (2004) studied the effect of different levels of nitrogen and phosphorous in cauliflower. There is no significant difference between 100 and 140 kg N/ha and 80 kg P<sub>2</sub>O<sub>5</sub> kg/ha recorded the highest value for number of leaves/plant(19.44), curd diameter (16.42 cm), curd depth (10cm), curd

weight (740.38g), curd solidity (64g/cm<sup>2</sup>) and marketable curd yield (236.92 q/ha) as well as the highest benefit : cost ratio (6.81).

Sharma and Chandra (2004) assessed the effect of spacing (45 x 30, 60 x 45 and 75 x 45 cm and nitrogen levels (0, 120, 150, and 180 kg N/ha) on the physico- chemical traits of cauliflower. Data were recorded on compactness, chlorophyll content in leaves, N, P, Ca, Zn, Fe, protein and TSS content and ascorbic acid content in curds. In general, all parameters increased with increasing plant spacing and N level except for compactness of heads, which showed an opposite trend.

Kumar (2004) studied the effect of N, P and Boron (B) application at different rates on growth and yield of cauliflower. Three levels each of N and P<sub>2</sub>O<sub>5</sub> and two concentration of boron were applied. Higher N and P<sub>2</sub>O<sub>5</sub> rates increased the growth but higher concentrations of B did not.

Singh (2005) studied the influence of plant spacing (45 x 30, 45 x 45 and 45 x 60 cm), levels of nitrogen (50,100,150,200 kg N /ha) and phosphorous (50,100 and 150 kg P<sub>2</sub>O<sub>5</sub>/ha) on cauliflower cv. Pusa K-1. Nitrogen application at 200 kg N/ha and P<sub>2</sub>O<sub>5</sub> at 100 kg/ha gave the highest number, weight, diameter and yield of curd.

Magd *et al.* (2005) grew three cultivars of broccoli (Atlantic, Monotop and Atlantic hybrid) on sandy soil with five compound fertilizer treatments, ie, Zero,N:P:K at 1:1:1(30 limits each of NPK), 2:1:1, 1:1:2 to study the effect on growth, yield and head quality. Results indicated that increasing any of N,P or K ratio in the compound fertilizer improved vegetative growth, yield and head quality.

Feller and Fink (2005) reported that the marketable yield of broccoli increased significantly with increasing N application at the time of planting.

Top dressed was given 25 days after planting. Nitrogen application at planting (80 to 118 kg N/ha) gave higher marketable yield.

Jing *et al.* (2005) reported that the highest yield was obtained with application of the specialized compound fertilizer with N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O of 9-5-6 in broccoli. Application of specialized compound fertilizer increased the ball yields by 9.9% (164 kg/667m<sup>2</sup>) compared with the normal fertilizer application. The harvesting of balls also became easier and the quality of asparagus, broccoli improved as a result of an increase in weight and tightness of the lower balls.

Kadam *et al.* (2006) conducted a field experiment on cauliflower cv. Golden 80 at Rahuri, Maharashtra. Thirty day old seedlings were transplanted and fertilizers were applied at 60, 80, 100, 120 and 140% of recommended NPK doses. Fertilization with 80% of recommended dose resulted in the highest average plant height (95.90 cm), yield 554 q/ha, water use efficiency (18.95 q/ha-cm) and fertilizer use efficiency (230.9 kg/ha) and the lowest number of days required to harvest curds after initiation (13 days).

Brahma and Pookan (2006) studied effects of N, P and K on yield of broccoli. The study was conducted at Assam Agriculture University, Jorhat. They observed maximum yield of 18.11 t/ha with the treatment of 200 kg N, 120 kg P<sub>2</sub>O<sub>5</sub> and 80 kg K<sub>2</sub>O per hectare.

Mahmud *et al.* (2007) reported maximum head yield (16.57 t/ha) of broccoli with the treatment combination of 120 kg N, 120 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O/ha, and this combination registered 385.92% higher yield over control. Yield increased with increase in nitrogen application up to 120 kg N/ha. Plant height and number of leaves/plant also increased with increasing rate of nitrogen application.

Du- caiyan *et al.* (2008) studied absorption pattern of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O by cauliflower var. Botrytis and the effect of different NPK treatments on head yield. The experiment was conducted at China and the results showed that the head yield significantly lower in plots without fertilizer compared to plots with fertilizers of 450 kg/hm<sup>2</sup> N, 225 kg/hm<sup>2</sup> P<sub>2</sub>O<sub>5</sub> and 337.5 kg/hm<sup>2</sup> K<sub>2</sub>O. The amount of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O observed by cauliflower was N > P<sub>2</sub>O<sub>5</sub> > K<sub>2</sub>O, but the proportion of fertilizer absorbed differed various growth periods.

Ranawat *et al.* (2008) reported that application of 100 kg N/ha produced significantly taller plants than control. The highest value for head diameter (16.82 cm), average leaf size (3888.16 cm<sup>2</sup>), curd number (6.10), plant spread (706.94 cm<sup>2</sup>), as well as average curd weight (152.79 g) and yield (119.01 q/ha) were obtained at 100 kg N/ha.

## **2.2 COMPARATIVE EFFECTS OF ORGANIC MANURES IN COLE CROPS**

Bahadur *et al.* (2004) conducted a trial in cabbage with four organic manures, viz. FYM, Press mud, digested sludge and vermicompost in combination with three bio-fertilizers – *Azospirillum*, VAM and PSM. When the characters were assessed out over the bio-fertilizers for the organic manures, it was found that the number of inner leaves (30.7), the head weight (1532 g) and the head yield (573.69 q/ha) were the highest under press mud compared to other organic manures. The lowest value for number of inner leaves was 26.9 under vermicompost, for head weight, 1374.44g under FYM and for head yield 523.36 q/ha under FYM.

Chatterjee *et al.* (2005) conducted a field trial on broccoli with three organic manures, viz. cow dung, poultry manure and mustard oil cake in combination with biofertilizer I (*Azotobacter* + phosphate solubilizer and potash mobilize) and bio fertilizer II (*Azotobacter* + VAM + potash mobilize) at BCKV, Mohanpur, West Bengal. The treatments were compared with the

control having recommended dose of fertilizers: N-150, P<sub>2</sub>O<sub>5</sub> 60 and K<sub>2</sub>O 80 kg/ha. The highest yield (124.07 q/ha), maximum curd weight (335 g) and the highest benefit: cost ratio (6.49) was observed with the recommended dose of inorganic fertilizers. Among the organic manures, the highest yield (103.7 q/ha), maximum curd weight (280 g) and highest benefit: cost ratio (4.46) was obtained with mustard oil cake in combination with biofertilizer II. The highest chlorophyll content and ascorbic acid content was with poultry manure.

Sanwal *et al.* (2005) studied effects of organic manures, *viz.*, FYM, Poultry manure, Pig manure, rabbit manure and Neem shield alone and in combination with natural growth promoters such as Panchakavya and Amritpani in broccoli were conducted at Meghalaya. When the organic manures were compared, the ascorbic acid content of floral part was the highest (52.89 mg/100g) under poultry manure and at par (52.46) with FYM. The total sugar content was the highest (39.56 %) under neem shield, but the protein content was the lowest (3.28%) under the same treatment. All other organic manures gave significantly higher protein content and lower sugar content in the floral parts compared to neem shield.

Maurya *et al.* (2008) conducted a field trial on broccoli cv. Fiesta at Pantnagar over two consecutive years. There were 9 treatments of which four were only organic manure *viz.*, FYM, Neem cake, vermicompost, and poultry manure. When the two years data for plant height, head weight and head yield were examined, the poultry manure was found to be the best with the highest values of 61.12 cm, 344.00 kg and 149.74 q/ha respectively for these characters, followed by vermicompost in which the values were 60.37 cm, 337.33 kg and 147.57 q/ha.

### **2.3 EFFECT OF BIO-FERTILIZERS IN COLE CROPS**

Bahadur *et al.* (2004) conducted an experiment in cabbage with four organic manures, viz., FYM, Press mud, digested sludge and vermicompost in combination with three bio-fertilizers i.e., *Azospirillum*, VAM and PSM. When the characters are average out over the organic manures for the biofertilizers, it was found that the number of inner leaves (29.8), head weight (1458.34 g) and head yield (552.80 q/ha) were the highest under phosphate solubilizing micro-organism (PSM). The lowest values for these characters were 28.0 for number of inner leaves under VAM, 1379.59 g for head weight under *Azospirillum* and 526.40 q/ha for head yield under *Azospirillum*.

Manivannan and Singh (2004) studied the effect of bio-fertilizers – *Azospirillum sp.* And *Azotobacter sp.* Applied at 5.0 and 10.0 %, on the growth and yield of sprouting broccoli cv. Fiesta. The experiment was conducted at Allahabad Agriculture Institute, Allahabad, U.P. The maximum plant height (41.72 cm), biomass yield/plant (1.089 kg) and number of frauds/head (15.00) was recorded in plants applied with 5% *Azotobacter sp.*, *Azospirillum sp.* At 5% gave the maximum number of slips/fraud (32.00), curd diameter (17.30 cm), plant spread (62.20 cm) and yield (55.57 t/ha).

### **2.4 INTEGRATED NUTRIENT MANAGEMENT OF COLE CROPS**

Intensive cropping coupled with mismatch of nutrient supply in terms of fertilizer application and nutrient removal by crop results in depleting of plant nutrients in soil. Integrated use of different sources of plant nutrients is necessary to check nutrient depletion and conserve soil health. The components of an integrated nutrient supply system include chemical fertilizers, organic manures, green manuring and bio-fertilizers and integrated nutrient management (INM) involves combined use of two or

more of these components. INM aims at replacing a part of chemical fertilizers by organics and bio-fertilizers so as to replace cost of cultivation, increase productivity and maximize other soil health.

#### **2.4.1 Integrated nutrient management of broccoli**

Sharma (2000) studied the efficacy of integrated nutrient management in broccoli using “green head” variety. The experiment was conducted at Lari, H.P. and the results showed that integration of organic manure and chemical fertilizer application significantly increased the head yield over control and chemical fertilizers alone. The treatments 175 kg N, 75 kg P<sub>2</sub>O<sub>5</sub>, 60 kg K<sub>2</sub>O/ha + FYM 12.5 t/ha recorded the maximum yield (63.12 q/ha) which was at par with N150, P<sub>2</sub>O<sub>5</sub> 75 and K<sub>2</sub>O 60 + FYM 12.5 t/ha (57.59 q/ha) but significantly superior rest of the treatments in terms of yield and net profit.

Dufault *et al.* (2001) conducted a field trial to evaluate shrimp biosolids (SB) which is a valuable source of N,P,K and Na with and without an inorganic fertiliser source (Osmocote 14N-6P-12K0 in broccoli at USA. Yield of marketable heads per hectare varied with SB: Osmocote (OSM) ratios. OSM at 75 kg/ha in combination with 9mt of SB/ha increased head yield /ha significantly compared to lesser rate of each fertiliser source. The biological yield increased by 13% with OSM at 150 kg/ha and SB at 9mt/ha but if OSM was increased to 300 kg/ha, yield decreased by 21%.

Wange and Kale (2004) studied the growth and yield response of broccoli to 12 different treatments of biofertilisers (*Azotobacter* and *Azospirillum*) and N levels (100,125 and 150 kg/ha) in medium black soil of Pune, Maharashtra. The treatment of *Azotobacter* and *Azospirillum* with 150 kg N /ha was significantly superior to the recommended dose of fertiliser alone. The crop responded better to biofertilisers at higher levels of N.

Sanwal *et al.* (2005) studied the effects of organic manures and natural growth regulators on the chemical composition of flowers and stems of broccoli, cv. Hybrid Fiesta. The treatments included farmyard manure (FYM) at 20 t/ha; poultry manure, 10t/ha; pig manure, 11t/ha, rabbit manure,11t/ha; neem shield 4.5t/ha; FYM at 16t/ha + 4 sprays of Panchakavya; FYM at 16 t/ha + 4 sprays of Amritpani; poultry manure at 8t/ha + 4 sprays of Panchakavya; poultry manure at 8t/ha + 4 sprays of Amritpani, and 100% RDF of NPK @ 150:60:80 kg/ha. Foliar spray of Panchakavya and Amritpani at 10% was made at 15, 30, 45 and 60 days after planting. Floral parts showed higher values for dry matter, carotenoid, total soluble solids, ascorbic acid and protein content but lower values for fiber content, reducing sugar, total sugar and nitrate than the stem. Integrated use of organic manures and natural growth promoters resulted in higher dry matter, total soluble solid, reducing sugar, total sugar and ascorbic acid content but lower fiber content in stems and flower than NPK application in the form of fertiliser.

Chatterjee *et al.* (2005) evaluated the effects of organic amendments on broccoli hybrid “Green Country” in the experiment carried out at BCKV, Mohanpur, West Bengal. The treatments were: T<sub>1</sub>- cow dung + biofertiliser-I (*Azotobacter* + phosphate solubilizer + potash mobilizer) ; T<sub>2</sub> poultry manure + biofertiliser-I; T<sub>3</sub> mustard oil cake + biofertiliser-I ; T<sub>4</sub> cowdung + biofertiliser –II (*Azotobacter* + VAM + potash mobilizer) ; T<sub>5</sub> Poultry manure + biofertiliser-II ; T<sub>6</sub> Mustard oil cake + biofertiliser –II and T<sub>7</sub> recommended dose of chemical fertilizers @ 150:60:80 kg N:P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O kg/ha. The highest curd yield (124.07 q/ha) was obtained from T<sub>7</sub> (inorganic fertilizers which also gave the highest cost-benefit ratio (1:6.49). Among the organic sources the treatment mustard oil cake + biofertiliser-II (T<sub>6</sub>) gave the highest curd yield (103.70 q/ha). T<sub>2</sub> (poultry manure + biofertiliser-I) produced curds with highest chlorophyll

content (38.30 mg/100g), T<sub>5</sub> (poultry manure + biofertiliser-II) produced curds with highest ascorbic acid (83.60mg/100g) and total sugar content (3.50%).

Sharma *et al.* (2005) studied the integrated use of chemical fertilizers and farmyard manure in broccoli at Kinnaur, H.P. There were eight treatments, i.e., 0, 50, 75, 100, 125 and 150 % of recommended dose of NPK (120:60:60 kg/ha) along with farmyard manure at 20 t/ha, 100% NPK alone and a control. Field attributing traits and marketable yield of broccoli increased linearly with increasing levels of NPK. The highest marketable yield (13.63 t/ha) was recorded under 150% NPK + farmyard manure at 20 t/ha, yield recorded at 75% NPK along with farmyard manure 20t/ha was at par with 100% NPK alone. The highest net returns of Rs 1,32,220/ha was recorded in 150% NPK + farmyard manure 20t/ha with benefit: cost ratio of 3.27.

Singh *et al.* (2006) evaluated different sources of nutrients and their combinations along with different plant spacing to maximize yield in broccoli, cv. Fiesta at Varanasi, U.P. The treatments were 100:50:50 kg NPK/ha, 10 t treated sewage sludge per hectare; 20 t FYM/ha; 10 t press mud/ha; 5t sewage sludge /ha + half the recommended dose of NPK; 5 t press mud/ha + half the recommended dose of NPK, 10t FYM/ha + half the recommended dose of NPK and the control with 3 spacing, i.e., 45 X 30 cm, 45 x 45 cm and 45 x 60 cm. Data were recorded for plant height, number of leaves/plant, curd initiation, curd maturity and curd yield.

Abou *et al.* (2006) studied the response of 5 broccoli varieties to four nitrogen sources in a split plot design in the experiment carried out at Cairo, Egypt. The varieties were in main plots and sources of nitrogen in sub plots. The nitrogen sources were cattle manure 50% (40N unit/fed), cattle manure 100% (80N unit /fed), poultry manure 100% (80 N unit/fed) and chemical fertilizer (80N unit/fed). The highest plant height and number of leaves/plant

were under 100% cattle manure and lowest under chemical fertilizers. Poultry manure application increased the total yield and quality. N, P, and K content in heads were under poultry manure. Among the 5 cultivars used, "Southern State" and was the best yield closely followed by perineum.

Raghav and Kamal (2007) evaluated the effect of vesicular arbuscular mycorrhizas (VAM) and inorganic fertilizers on growth yield and quality of broccoli. Application of mycoplex at 250 kg/ha + N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @60:50:50 kg/ha respectively produced the highest plant height (44.3 cm), plant spread (3436.4 cm<sup>2</sup>), leaves/plant (18), length of largest leaf (52.1 cm), width of largest leaf (22.1 cm), and highest curd weight (338.0 g). The treatment also improved quality characters viz., chlorophyll (39.7 mg/100g), reducing sugar (2.40%) and Vitamin A (375.1IU) content.

Bhardwaj *et al.* (2007) studied the effects of nitrogen application at 0,25,50,75 and 100% of the recommended rate of 105 kg N/ha (N<sub>1</sub>,N<sub>2</sub>,N<sub>3</sub> and N<sub>4</sub>) and *Azotobacter* inoculation (2kg/ha or 1kg/10l of water for seedling inoculation) on growth and yield of broccoli cv CBH-1 at Bichpuri, Agra, U.P. Plant height and plant spread increased with N rate up to N<sub>3</sub> being on par with N<sub>4</sub> for these traits. Main stem diameter and number of fully opened leaves increased with increase in N rate. The highest average curd weight (260.32g) and curd yield (133.60 q/ha) were obtained with N<sub>4</sub>. The average curd size was the largest under N<sub>3</sub> and N<sub>4</sub> (18.48 and 18.52 cm respectively). The *Azotobacter* inoculation produced greater plant height (39.46 cm), main stem diameter (2.71cm), plant spread (61.25 cm), number of fully opened leaves per plant (18.82), average curd weight (240.16 g), average curd size (17.69cm) and curd yield (119.67 q/ha) compared to control (no inoculation). The results revealed that *Azotobacter* inoculation could reduce the N application rate 25% without adversely affecting productivity yield of broccoli.

Ouda and Mahadeen (2008) conducted a trial on broccoli with combinations of four organic manure doses (0, 40, 60 and 80 t/ha) and three inorganic fertilizer doses (0, 30 and 60 kg/ha). The treatment of 60 t of organic manure + 60 kg inorganic fertilizers produced the highest yield (40.05 t/ha). Leaf number/plant, chlorophyll content and head diameter were higher under combination of organic manure and inorganic fertilizers than their individual application.

Sharma *et al.* (2008) conducted a field experiment at Lahaul and Sapidi, India to find out the response of broccoli to integrated nutrient management using organic manure, *Azotobacter* along with chemical fertilizers. There were 12 treatments combinations of three levels of NPK (50,75, and 100% of recommended dose) integrated with 2 levels of cowdung manure (CDM) at 10 and 20 t/ha and inoculation with *Azotobacter* and no inoculation. Integration of *Azotobacter* with the recommended practice of 20t/ha CDM + 100% recommended dose of NPK produced the highest marketable head yield. This treatment combination also gave the highest leaf width, apical and lateral curd weight and total yield/plant as well as the highest net return with benefit-cost ratio of 3.49.

Maurya *et al.* (2008) conducted a field trial to study the effects of organic manures and inorganic fertilizers on growth, yield and economics of broccoli cv., Fiesta. The treatments were: recommended dose of fertilizers (RDF 120:60:60 kg NPK/ha); farmyard manure (FYM) at 20 t/ha; FYM at 10t/ha + 50% RDF; vermicompost at 5t/ha; vermicompost at 2.5t/ha + 50% RDF; poultry manure at 5 t/ha; and poultry manure at 2.5 t/ha + 50% RDF. In 2005-06 poultry manure + 50% RDF and FYM + 50% RDF gave the highest plant height but in 2006-07 poultry manure + 50%RDF, vermicompost + 50% RDF, RDF and poultry manure gave the tallest plants. The number of fully opened leaves in both the years was highest under poultry manure + 50%

RDF. Leaf length was highest under poultry manure + 50% RDF and vermicompost + 50% RDF. Poultry manure + 50% RDF, FYM + 50%RDF and vermicompost + 50% RDF registered the greatest head weight in 2005-06, whereas, poultry manure + 50% RDF was superior for this trait in 2006-07. The highest yield of 155.47 q/ha in 2005-06 and 191.41 q/ha in 2006-07 were obtained with poultry manure + 50%RDF.

Ouda and Mahadeen (2008) investigated the effects of organic manures and inorganic fertilizer on broccoli in the experiment conducted at Agricultural Research Station, Rabba, Jordan. The treatments consists of organic manures (chicken, sheep and cowdung manure in a ratio of 1:1:1 at 4 doses of 0,40,60 and 80 t/ha and inorganic fertilizer (Green leaves 20-20-20 + trace elements) at 3 doses of 0,30 and 60 kg/ha. Application of 60 kg inorganic fertilizer with 60 t organic manure per hectare produced the higher yield (40.05 t/ha). Head number /plant, chlorophyll content and head diameter were higher when a combination of organic and inorganic fertilizers was used compared to their individual application. The macro-nutrients and (NPK) and micro-nutrient (Fe, Mn, and Zn) contents increased with application of either organic manner or inorganic fertilizer compared to control. Application of a combination of organic manures and inorganic fertilizers gave the best values for all tested parameters.

Chaurasia *et al.* (2009) reported the effect of integrated nutrient management and spacing on yield, quality and economics of broccoli cv., fiesta. The trial was conducted at Indian Institute of Vegetable Research, Varanasi during the rabi season of 2003-04 and 2004-05. The treatment combinations were control, NPK (100:50:50 kg/ha), treated sewage sludge (10 t/ha, press mud (10t/ha); FYM (20 t/ha); 50% of NPK + sewage sludge ( 5 t/ha) and 50% of NPK + FYM (10t/ha) with three spacings i.e., 45 x 30 cm, 45 x 45 cm and 45 x 60 cm. it was revealed that the maximum curd yield,

maximum net profit and cost-benefit ratio was noted with application of press mud alone or in combination with 50% NPK and planted at 45 x 60cm spacing during both the years.

#### **2.4.2 Integrated nutrient management in other Cole crops**

Bahadur *et al.* (2004) conducted a field experiment in cabbage with four different organic manures, viz FYM, pressmud, digested sludge and vermicompost in combination with three biofertiliser viz. *Azospirillum*, VAM and phosphate solubilizing microorganism (PSM) with recommended dose of inorganic fertilizers (120 N:60P<sub>2</sub>O<sub>5</sub>:80 K<sub>2</sub>O) as control at Gandhinagar, Varanasi, U.P. Significant improvement in number of inner leaves and head weight was observed when pressmud was applied and seedlings were inoculated either with VAM or PSM. A significant improvement in head weight was also found with digested sludge and seedlings inoculated with PSM. Head diameter was influenced significantly with organic manures and biofertilisers. Significantly higher head yield over control was obtained with pressmud + VAM (602.67 q/ha), pressmud + PSM (587.40 q/ha) and DS + PSM (570.80 q/ha). These treatments gave 22.6, 19.5 and 16% more head yield, respectively than control giving 491.33 q/ha.

Choudhury *et al.* (2004) studied the effects of integrated use of organic manure, biofertilisers and chemical fertilizers on the nutrient status of soil and the productivity of cauliflower at Jorhat, Assam. The treatment combinations included farmyard manure (FYM), phosphate solubilizing bacteria (PSB), Rock phosphate, *Azotobacter* and inorganic fertilizers. The organic carbon and available nitrogen status of soil increased significantly with conjugative use of FYM, biofertilisers and inorganic fertilizers. Available nutrients like N,P, and K in soil increased significantly with the application of organic and microbial sources of nutrients in combination with fertilizers over fertilizers

alone. Plant growth parameters and yield of cauliflower were highest with application of FYM, *Azotobacter* and PSB along with inorganic fertilizers.

Narayanamma *et al.* (2005) investigated the effects of biofertilisers in combination with inorganic fertilizers on the growth, yield, quality and soil nutrient status after harvest of cauliflower in the experiment carried out at Hyderabad. The treatments comprised recommended dose of NPK 180, 60 and 60 kg/ha(RDF). *Azospirillum* + 75% N and total of P and K ; *Azospirillum* + 100% N,P and K ; *Azotobacter* + 75% N and total P and K ; *Azotobacter* + 100% N,P and K ; phosphate solubilizing bacteria (PSB) + 75% P and 100% N and K ; PSB + 100 % N,P and K ; vesicular arbuscular mycorrhizas (VAM) + 75% P and 100% N and K; VAM + 100% N,P and K. The biofertilisers were applied by seedling root dip method. Application of biofertilisers along with the inorganic fertilizers produced significantly higher yield (18.6 – 22.6 t/ha) compared to 16.5 t/ha under RDF. Application of VAM + 100% RDF recorded significantly higher yield (22.6 t/ha) compared to application of all other biofertilisers + inorganic fertilizer but was comparable with VAM + 75% P and 100% N<K. Application of VAM and any level of P + 100% NK, *Azospirillum* and *Azotobacter* with 100% NPK and 75% N + 100% PK recorded significantly higher Vitamin C content (59.7-60.4 mg/100g) compared to RDF and other treatments (53.9-55.2 mg/100g). Total N,P and K contents of curd were significantly higher with the biofertilisers compared with RDF. The highest benefit cost ratio of 2.96 was observed with the application of VAM + 100% RDF and lowest (1.95) with RDF application.

Singh and Singh (2005) studied the response of cauliflower cv. Snowball-16 to four biofertilisers (*Azotobacter*, *Azospirillum*, Phosphate solubilizing bacteria and vesicular arbuscular mycorrhiza) and two levels of NPK 75 and 100% of RDF(120 N: 60 P<sub>2</sub>O<sub>5</sub>: 60 K<sub>2</sub>O kg/ha) in the experiment conducted at Faizabad, Uttar Pradesh. Data were recorded on plant height, number of leaves,

average curd weight, ascorbic acid content and yield. *Azospirillum* + 100% of RDF NPK recorded the highest value for all growth, yield and quality parameters studied. This treatment also recorded the highest net return (Rs. 53,965/ha) and benefit cost ratio of 2.23

Sable and Bhamare (2007) conducted an experiment in cauliflower with three levels of nitrogen 0, 75 and 100% of RDF and four levels of biofertilisers (no inoculation, *Azospirillum*, *Azotobacter* and combination of both at Parbhani, Maharashtra. Out of twelve treatment combinations, the best was 75% nitrogen (120 kg N/ha) + *Azotobacter* and *Azospirillum* combined & which significantly increased ascorbic acid content (87mg/100g) and protein content (18.62%) in curds, total nitrogen content in plant (2.98%) and compactness of curd (97.39%).

Supe and Marbhal (2008) conducted an experiment to study the effects of organic manures with graded level of nitrogen on growth and yield of cabbage was undertaken at Department of Horticulture, Mahatma Phule Krushi Vidyapeeth, Rahuri, Maharashtra. Average weight of head, average weight of leaves, number of leaves per plant, girth of head and days required for harvesting were found to be significantly superior in treatment where 50% of N was applied through organic sources over full dose of 100:50:50 NPK kg/ha from inorganic sources. However, treatment of 50% nitrogen was from organic sources on par with the treatment where increased dose of NPK (125:62.5:62.5 kg/ha) was applied.

Velmurugan *et al.* (2008) reported that cauliflower showed better response to application of organic manures and biofertilisers. Application of recommended dose of fertilizers, FYM 15t/ha + NPK @ 50:100:50 kg/ha as basal and 50 kg N/ha as topdressing, 45 days after transplanting recorded the highest plant height (32.56 cm), number of leaves (26.60), length of leaves (30.55 cm), width of leaves (15.46 cm), leaf area (472.303 cm<sup>2</sup>) and leaf area index (0.175) as compared to control. Combined application of vermicompost

and Panchakavya gave the highest total dry matter content (211.99 g/plant. Application of recommended dose of fertilizers recorded the highest curd length (15.66 cm), curd width (17.21 cm) and curd weight (340.12g/plant compared to control. The experiment was carried out at Jallipatti, Udumelpet, Tamil Nadu.

Bocek *et al.* (2008) studied the effects of three dried organic/ organ mineral fertilizers on yield and quality of early maturity cauliflower cv. Gameta was carried out at Zabcice (South Moravia, Crech Republic. The treatments were Agromin T., Agro, dvorecky agro ferm, Cattle farmyard manure and solo mineral fertilizers compared to an unfertilized control. All plots except control were fertilized to get same level of nutrients as determined by soil analysis and the chosen target yield. Agromin T significantly increased the weight of above grinded biomass and total marketable yield. All organic fertilizers significantly increased head weight and head diameter in comparison to both the unfertilized control and mineral fertilizers. Ascorbic acid content was not significantly affected by the fertilizers. The highest value for ascorbic acid content was observed under farmyard manure and the lowest under Dvorecky agroferm. Dried fertilizers had no positive effect on ascorbic acid content and total solids as compared to farmyard manure. Agromin T produced significantly under amounts of dry matter. Solo mineral fertilizer resulted in highest levels of nitrates in heads. Agro and farmyard manure significantly increased the levels of nitrates in heads compared to control. The dried granulated fertilizer Agromin T, Agro and Dvorecky agroferm were shown to be good alternatives to bulky farmyard manure for early harvest of cauliflower.

Singh *et al.* (2009) conducted an experiment at MES, N.D. University of Agriculture and technology, Kumarganj, Faizabad during 2005-06 and 2006-07 to investigate the effects of different integrated nutrient management levels on growth, yield and economics of cauliflower. The treatment combinations consisted of control, FYM (20 t/ha) + NPK (120:60:60 kg/ha), vermicompost

(3 t/ha) + NPK (120:60:60 kg/ha), FYM (20 t/ha) + 50% of NPK, vermicompost (3 t/ha) + 50% of NPK, 50% of FYM + 50% NPK + *Azotobacter* (1.5 kg/ha), 50% vermicompost + 50% NPK + *Azotobacter* (1.5 kg/ha), 50% FYM + 50% vermicompost + 50% of NPK + *Azotobacter* (1.5 kg/ha) with two cultivars of cauliflower viz. Snowball-16 and Madhuri. Plant height, number of leaves per plant, stalk length, spread of plant, leaf size, index, length of main root, gross curd weight and yield increased significantly with the application of 50% FYM + 50% vermicompost + 50% NPK + *Azotobacter* (1.5 kg/ha). Between the two varieties, Madhuri gave the better yield with maximum benefit: cost ratio than Snowball-16 during both the years.

Sharma *et al.* (2009) carried out an investigation at Lahaul and Spiti district of Himachal Pradesh during summer 2003 and 2004 to find out the response of cauliflower to bioinoculants and graded level of fertilizers. There were 16 treatment combinations of four levels each of bioinoculants (no inoculation, dipping of seedlings in the culture of *Azotobacter*, phosphate solubilizing bacteria and their combinations and NPK fertilizers (0, 50, 75 and 100%) of recommended dose of 125:75:60 kg N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O /ha. Applications of bio-inoculants alone and in combination significantly increased the marketable curd yield and its attributing traits, net returns, NPK uptake and also building up soil fertility. The increasing levels of NPK also followed the similar trend. Application of recommended dose of NPK in combination with *Azotobacter* and phosphate solubilizing bacteria registered significantly higher marketable curd yield (9%) over recommended dose of NPK along with maximum net returns and benefit cost ratio (3.99), which is also at par with the application of 75% NPK + *Azotobacter* + Phosphate solubilizing bacteria. Thus, there was a saving of 25% NPK fertilizers.

