CHAPTER-II

REVIEW OF LITERATURE

Rice and potato are the staple food of about two-third population of our country and contribute a major energy source for human community. It is a fact that both the crops are very exhaustive in nature and exert tremendous pressure on soil health. This simulate the need for utmost care in attaining a delicate balance among various source of inputs with special attention to nutrient management through conjunctive use of organic and inorganic sources of plant nutrients to sustain the crop productivity and soil fertility. The review on the current study entitled “Effect of integrated nutrient management in rice-potato cropping system” is an attempt to provide an insight to state of research conducted elsewhere.

Cropping systems based approach was felt essential only during last two decades to sustain crop productivity levels attained through high yielding modern varieties and improved agro techniques. Efficient cropping systems with respect to biological potential and efficiencies of land, water and nutrient use are to be identified to increase resource use efficiency of a multiple cropping systems (Yadav et al., 1998). Multiple cropping with diversified crops should be followed by integrated management of different inputs of crop production.

2.1 Integrated nutrient management in rice

Mahapatra et al. (1985) opined that under rice-rice sequence the fields require replenishment of fertility both through organic and inorganic sources of plant nutrients as organic sources play an important role in sustained productivity of tropical region soils, particularly in lateritic soils which remain conspicuously low in organic matter content. It is well supported by Rathore (1996) from an experiment in farmer’s field at Bilaspur who found that
application of FYM alone could register an increase in net return by ₹876/ha over control (₹3081/ha). But Dubey et al. (1997) contradicted the INM approach in rainy season and found less yield of kharif rice under INM than recommended dose applied through inorganic sources only.

Several workers have found that FYM applied either alone or in combination with inorganic fertilizer enhanced the performance of rice crop. However, the influence of FYM or crop yield was more pronounced when applied in conjunction with inorganic fertilizer (Rajput and Warsi, 1991; Mondal et al. 1994).

An interesting report by Panda et al., (1991) states that in irrigated rice N levels at 60 kg/ha, combined application of urea and sesbania green manure/Azolla/FYM at the ratio of 1:1 on N level basis, produced comparable yield to that of urea alone, while at N 90 kg/ha INM practices involving sesbania green manure or Azolla dual crop were superior to the inorganic sources of N.

However, Hedge (1998) summarized the work done on INM at different locations and justified the use of integrated nutrient supply for sustained productivity and advocated 25-50% substitution under semi arid ecosystems at Ludhiana, Kanpur and Navsari.

Bandopadhaya and Puste (2002), Parihar (2003) and Yadav et al. (2005) also supported the use of INM in rice with substitution of chemical fertilizers by organic sources of nutrition to the extent of 25-50 percent. However, Roul and Sarawgi (2005) advocated 5-10 t FYM/ha over and above the 100 percent RDF for higher yield, N content and N uptake in rice.

### 2.1.1 Effect of INM on yield attributes of rice

Mondal et al. (1994) observed the yield attributing characters such as number of effective tillers/m², fertile grains per panicle and 1000 grain weight
improved significantly when rice crop was fertilized with 75% of the recommended dose of NPK along with 10 t FYM/ha.

Choudhury and Thakuria (1996) also reported greater number of effective tillers/hill owing to green manuring of *sesbania* in rice.

Singh and Verma, (1999) from an experiment at Ghazipur, Uttar Pradesh found maximum yield attributes and yield (4.07 t/ha) of rice due to application of FYM @ 10 t/ha + 50% recommended dose of fertilizer (120:60:60 kg N:P₂O₅:K₂O/ha).

Dwivedi and Thakur (2000) from their study entitled ‘effect of organics and inorganic fertility levels on productivity of rice crop’ reported that use of *Sesbania canabina* at the rate of 14 tonnes per hectare could produce significantly higher number of panicle/m², length of panicle, number of fertile grains per panicle and thousand grain weight in rice crop.

From Terai soils of West Bengal Choudhury and Kabi (2002) reported that application of 60 kg N/ha along with *Azospirillum lipoferum* could bring significant increase in number of effective tillers/hill, length of panicle and number of fertile grains/panicle and could save 30 kg N/ha.

Bandopadhaya and Puste (2002) from red and laterite soils of West Bengal reported higher yield (42.4 q/ha) and yield attributes of rice, lentil, gram and pea when 25% of chemical fertilizer in rainy season was replaced by FYM (3t/ha).

Results of INM practices in scented rice carried out at Raipur, Chhatisgarh by Jha *et al.* (2004) indicated that plant height, leaf area index, number of effective tillers/m² were significantly higher when inorganic fertilizer was applied in combination with cow dung urine mixture or farm yard manure.
These results were in agreement with the findings of Sreedevi and Sreedharan (1999).

Mandal and Adhikary (2005) conducted a trial in clay loam soil of West Bengal and reported that plant height, effective tillers/hill, number of grains/panicle and 1000 grain weight were significantly higher in the treatment receiving 50% N through chemical fertilizer and 50% N through FYM.

Nanda et al. (2007) from a study on INM in rice-rice system conducted in acid lateritic soil of coastal ecosystems of Orissa reported higher plant height, effective tillers/hill, panicle length, number of fertile grains/panicle and 1000 grain weight under combined application of 50% N through chemical fertilizers and 50% N through green manuring of Azolla.

Natarajan et al. (2008) from Tamilnadu reported significant increase in plant height and number of effective tillers/hill in rice with combined application of 50% N through Sesbania aculeata and rest 50% N through inorganic fertilizer.

### 2.1.2 Effect of INM on rice yield

Higher yield of rice owing to combined application of green manure and recommended dose of inorganic fertilizer was reported by Pandey and Tripathy (1992).

Pramanik and Mahapatra (1997) reported that integrated use of organic and inorganic N sources significantly increased grain yield of rice (4.28 t/ha).

Singh and Verma, 1999 from an experiment at Gazipur, Uttarpradesh found maximum yield of rice (4.07 t/ha) due to application of FYM @ 10 t/ha along with 50% recommended dose of fertilizer (RDF) as more effective in producing higher yield of rice (63.3 q/ha) as compared to 56.2 q/ha through
100% RDF alone in sandy clay loam soils of Punjab. Prasad (2000) also reported that combined use of N increased the yield of rice compared to the entire recommended N supplied through chemical fertilizer alone.

Balasubramaniyan (2004) from Tamil Nadu reported combined application of green manure (*Sesbania rostrata*) with 100 kg N/ha could produce grain yield of 3.9 tonnes/ha in fine grained rice. The results are in confirmation with Velu and Rani Perumal (1999).

Mandal & Adhikary (2005) conducted a trial in clay loam soils of West Bengal, the results of which indicated that supply of 25 to 50% N through FYM along with chemical fertilizers could significantly enhance the grain yield of rice.

Singh *et al.* (2005) from a trial conducted in clay soils of Imphal reported that the highest yield was recorded by the application of 60 kg N from urea + *Azolla*. This result was in agreement with the findings of Hattab *et al.* (2000).

Aruna and Mahammad (2005) from Andhra Pradesh reported that conjunctive application of inorganic fertilizers and green manure/bulky organic manure significantly increased the grain yield of rice as compared to application of chemical source of N alone.

**2.2 Integrated nutrient management in Potato**

Potato is a very exhaustive crop and demands a high level of nitrogen fertilization for higher and sustainable yield level. Nitrogen management is one of the major factors to attain higher productivity of potato. Integration of various sources of nitrogenous fertilizers is more appropriate because this not only reduces the use of inorganic fertilizers but also is an environment friendly approach. Moreover, in recent years the price of inorganic fertilizers has gone up considerably which has increased the cost of production. In this context it is imperative to popularize the use of locally available organic sources
especially biofertilizers which is of low cost, pollution free, cheaper and renewable. Among the different nutrients, nitrogen is the main limiting nutrient, which is responsible for vegetative growth, increased tuber number and tuber size in potato needs to be applied at optimum dose for obtaining higher tuber yield (Kaur et al., 2001).

2.2.1 Effect of INM on yield attributing characters of potato

Rajwade et al. (2000) from U.P reported that application of FYM or Nadep compost along with 75% recommended dose of chemical fertilizer resulted in significantly higher LAI and dry matter accumulation in potato.

Datt et al. (2002) and Emin et al. (2004) reported that organic manures are not only the source of nutrients but also have stimulatory effect on better efficiency of chemical fertilizers.

Das et al. (2004) from a field experiment conducted in sandy loam soil of West Bengal reported that combined application of 60% N as vermicompost along with 40% N as urea resulted in higher plant height (57.5 cm), dry matter accumulation (613.2 g/m²), LAI (1.57), number of tubers/plant (6.00) and tuber weight/plant (305.1 g) at 75 DAS as compared to application of inorganic fertilizers only. Similar findings were reported by Rani and Srivastava (1997).

Singh and Gupta (2005) from Central Potato Research Station, Shillong reported the results of an experiment conducted in sandy clay loam soil with medium soil fertility, which exhibited that application of FYM along with biofertilizer resulted in taller plants, more number of stems/hill and tuber yield of potato. Similar findings were obtained by Singh (2002).

Sud et al. (2005), from studies conducted on brown hill soils revealed positive effect of P and K application through farmyard manure and inorganic
fertilizers on total tuber yield, yield of large sized tubers as well as nutrients uptake by potato under rain fed conditions. Application of N enhanced protein content while FYM and K improved vitamin C content.

Singh and Kushwah (2006) from Central Potato Research Station, Gwalior reported that conjunctive use of FYM or Nadeep compost @ 30 tonnes/ha along with 75% RDF resulted in higher plant height and more number of tubers/ha as well as 45.6 tonnes of tuber yield/ha.

Kumar and Sharma (2007) reported higher plant height, no of fruits/plant and weight of fruits/plant in tomato due to combined application of FYM and Azotobacter along with chemical fertilizer.

Field experiments on integrated nutrient supply and management were conducted on sandy loam soil during 2003–2004 in mid hills of Shimla. The results revealed that combined use of organics and inorganics in the ratio of 1:3 significantly increased plant growth parameters, which was reflected in tuber yield and nutrients uptake. The higher tuber yield under integrated use of organics and inorganics was mainly due to higher proportion of large and medium size tubers (Sood, 2007).

Singh et al. (2007), from Modipuram, Uttar Pradesh indicated that the integrated application of organic (either 25% or 37.5% through FYM) and inorganic (75% or 62.5% through urea) sources of nitrogen proved to be effective in obtaining higher tuber bulking rate, tuber yield and the percentage of bigger tubers than that of 100% nitrogen application through inorganic sources. Application of bio-inoculants (VA Mycorrhiza and Azospirillum) in conjunction with organic and inorganic sources of nitrogen did not improve the growth and yield parameters significantly.
2.2.2 Effect of INM on yield of potato

Selvi and Selvaseelan (1999), from Tamilnadu reported that tuber yield of potato cv. “Kufri Jyoti” increased by 20% when FYM was applied with 100% NPK. Mushroom spent rice straw compost application increased the potato yield by 16%.

Mondal and Roy (2001) from farmers’ field trial in Nadia district of West Bengal reported significantly higher tuber yield of potato (29.68 t/ha) with combined application of 100% recommended dose of chemical fertilizer and 10 t FYM/ha.

Khanda et al. (2005 a) reported that integrated use of FYM @ 10 tonnes /ha and 50, 75 and 100% recommended dose of NPK increased yield of potato, wheat and mustard over the corresponding N, P & K levels alone. The yield obtained from 75% RDF of NPK along with 10 tonnes FYM was at par with that of 100% RDF of NPK alone through inorganic sources.

Lal and Khurana (2007), from Hissar, Haryana studied the effect of biofertilizers, biodynamic compost and organic manure on potato, grown in potato-onion-guar sequence. During the crop season, no pesticide was used. Different treatments of organic manure recorded only 3.19–13.9% lower yield than the recommended dose of NPK. Use of biodynamic compost was useful in improving the tuber yield.

Upadhayay et al. (2007), from Modipuram reported that continuous raising of organic potato bio-dynamically on the same site, improved tuber production by 30–50%. A perusal of data on grade-wise tuber production revealed that bio-dynamically raised organic potato produced 8-11% more seed size tubers than inorganically fertilized crop.
Singh et al. (2007), from Central Potato Research Institute Campus, Modipuram, Uttar Pradesh reported that Integrated use of 25% vermicompost and 75% of NPK through inorganic fertilizers resulted in higher yield over inorganically raised crop at Modipuram in northwestern plains. At Shimla, radio tracer studies revealed higher 32P activity in potato leaves at critical growth stages with application of phosphorus-solubilizing bacteria.

A study was undertaken by Sarkar et al. (2007), during winter seasons of 2002–03 and 2003–04 at Kalyani, to evaluate the effect of integrated nutrient management on productivity and quality of potato under irrigated situation. Different levels of chemical fertilizers viz., 0, 50% of recommended dose of fertilizer (RDF), 100% RDF and 150% RDF, organic sources viz., pelleted form of organic manure (Biomax), karanja cake (Enmite) and crop residues were tested. The dry matter accumulation, tuber dry weight, tuber bulking rate and tuber yield were significantly higher under 150% RDF. The increase in tuber yield with 150% RDF over 100% RDF was 2.8%. Introduction of organic manure significantly improved plant growth which was ultimately reflected in tuber yield and quality. Among the organic sources, performance of pelleted form of organic manure was better.

Mohapatra et al. (2008) from West Bengal reported that conjunctive use of chemical fertilizers along with FYM resulted in maximum tuber yield (23.77 t/ha) as compared to application of inorganic fertilizers alone to potato crop.

2.3 Effect of INM on system productivity

Mondal et al. (1996), from the findings of their experiment on “effect of potassium, sulphur, farm yard manure and crop residues on the yield of rice, mustard and potato” in a Gangetic alluvial soil of West Bengal reported that rice grain yield was the highest (2.65 t/ha) with application of 60 kg N + 30 kg P₂O₅ + 30 kg K₂O + 10 t FYM/ha. Mustard seed yield was highest (1.08 t/ha)
with 80 kg N + 40 kg P$_2$O$_5$ + 40 kg K$_2$O + 20 kg S/ha. Potato tuber yield was the highest (28.3 t/ha) with 120 kg N + 100 kg P$_2$O$_5$ + 100 kg K$_2$O + crop residues in the system.

Singh et al. (1999) from Raipur, Chhatisgarh reported that combined application of unfertilized green manure along with urea-N to rice produced significantly higher grain yield (4.1 t/ha) and was at par with 80 kg N/ha through urea alone during both the years of investigation. The grain yield was 35.5% higher as compared to control. They also reported that combined application of FYM and urea to succeeding potato crop could record significantly higher tuber yield (13.1) in rice - potato system. They concluded that for sustaining the desired level of yield in both the crops organic manuring along with chemical fertilization to both the crops is essential and it saves up to 50% chemical N in rice-potato cropping system.

Roy et al. (2001), from Jalandhar, Punjab, carried out a field trial to develop an integrated nutrient management programme for a potato-sunflower - rice rotation. The experiment consisted of 10 fertilizer treatments i.e. combined application of 50, 100 and 150% of the recommended rates of inorganic nitrogen (N), phosphorus (P) and potassium (K) with farmyard manure (FYM) and in some cases zinc (Zn). Potato was the most nutrient-responsive crop followed by rice and sunflower. The results revealed that potato required NPK at 150% of the currently recommended rate for maximum tuber production (i.e. 270 kg N, 52 kg P and 150 kg K/ha). Application of FYM @ 30 t/ha with 270 kg of inorganic N/ha (FYM + N) was less effective than the use of NPK at 150% of the currently recommended rate. The effects of the FYM + N treatment were cumulative, especially on potato which was the most responsive crop.
Mondal and Roy (2001), carried out a field experiment in West Bengal, to study the effect of potassium applied with or without sulphur and farmyard manure, on the yield and nutrient uptake by crops in potato - jute - rice sequence under irrigated conditions. The highest tuber yield of potato, fiber yield of jute (3.40 t/ha) and grain yield of rice (4.40 t/ha) were produced when all the crops in the sequence received the nutrients through organic and inorganic sources. The percentage yield increase of potato, jute and rice in both organic manure and inorganic fertilizer treated plots were 26.2, 30.5 and 48.3, respectively.

Singh et al. (2002), from Central Potato Research Station, Jalandhar, Punjab studied the productivity and sustainability of potato-based cropping systems i.e. in potato-wheat-rice, potato-potato-maize-wheat-green manure, potato-potato-maize and potato-wheat-maize cropping systems under different fertilizer management schedules. Productivity was lowest when crops were treated with N alone (control). Biennial application of P, PK and FYM increased the mean productivity over the control by 16, 24 and 32%, respectively. The corresponding increase with their annual application was 25, 34 and 49%, while with application to alternate crops; it was 23, 31 and 48%. The productivity under all the treatments and cropping systems declined over the period with varying degrees. The rate of decline in productivity was highest in the control followed by biennial, annual and applications to alternate crops.

Chettri et al. (2004) conducted an experiment at Adisaptagram block seed Farm, West Bengal to evaluate the production potential and soil fertility build up in potato-groundnut- rice system as influenced by different levels of chemical fertilizers with or without farm yard manure and crop residue. The results indicated that tuber yield of potato (27.5 t/ha) and grain yield of rice (4.11 t/ha) obtained with the treatment receiving 75% of RDF + 10 t FYM/ha were statistically at par with that of 125% RDF and were significantly higher than the
treatments receiving 100%, 75% and 50% of the recommended dose without FYM. Similar results were obtained by Roy et.al.2001.

Khanda et al., 2005 while studying the productivity and economics of different rice based cropping sequences as influenced by integrated nutrient management on sandy clay loam soil of Kalyani, West Bengal reported maximum system productivity to the extent of 10,919 kg/ha from the treatment with 100% RD of NPK to all the crops in the sequence in conjunction with 10 t FYM/ha. They concluded that integrated use of NPK fertilizer and FYM increased the system productivity of rice-potato-sesame by 8.7% as compared to NPK fertilizer alone.

Sarkar and Mondal (2005) conducted a field experiment during kharif, rabi and pre-kharif seasons in West Bengal to investigate the effect of integrated nutrient management on the productivity of rice-potato-soyabean cropping system. The synthetic fertilizer treatments included 0, 50, 100 and 150% of the recommended dose of fertilizer (RDF) for each crop (N:P:K at 60:30:30, 120:100:100 and 30:60:40 kg/ha for rice, potato and soyabean, respectively). Organic fertilizer treatments were: no treatment; FYM @ 10 t/ha; compost with high bacterial content @ 1.33 t/ha; enmite (coarse neem seed + karanja cake + other oil cakes) @ 1.35 t/ha; and incorporation of crop residues after the harvest of each crop in sequence. The maximum yields (44.65, 299.32 and 18.95 q/ha) of rice cv. IET-4094, potato cv. Kufri Jyoti and soyabean cv. JS-335, respectively were obtained under 150% RDF + enmite. The net production value was highest (3.03) in treatments receiving 100% RDF + enmite.

2.4 Effect of INM on quality parameters of rice

Fertilizers would supply one or a few nutrients only and will not supply the enzymes and growth regulators. This is the reason for better quality of the
agricultural produces grown with combined application of organic and inorganic sources of plant nutrition and not due to differential functioning of the nutrients from organic manures and inorganic fertilizers (Kumaraswamy, 2005).

Raju and Reddy (2000) from an experiment on “integrated nutrient management in rice-rice system” at Maruteru in coastal Andhra Pradesh reported that highest carbohydrate (8498 kg/ha), protein (772 kg/ha) and bran oil (132 kg/ha) yield of the system was obtained when 50% N was substituted through *Sesbania* green leaf manure.

Hemalatha *et al.* (2000) from Tamil Nadu reported that use of organics i.e, FYM, *Dhaincha* and Sunhemp in rice field could enhance the crude protein content to 8.3% as compared to 7.8% without organics.

Priyadarsini and Prasad (2003) from Andhra Pradesh reported higher protein (7.80%) and amylase content (21.48%) of rice grain when the crop received 50% RDN through chemical fertilizer and 50% RDN through FYM + green manure as compared to 100% N through chemical fertilizer alone.

Mrudula *et al.* (2004) from Bapatla, Andhra Pradesh reported that 100% N through inorganic and additional 25% N through press mud could result in highest protein content of rice grain (8.15%) which is at par with 75% RDN through urea + 25% RDN through FYM (8.13 %). This corroborated the findings of Dixit and Gupta (2000).

However, Ghose (2005) from CRRI, Cuttack reported that application of *sesbania* / FYM @ 12.5 t/ha could produce 8.2% crude protein, 27% total amylase and 16% bran oil which is at lower side as compared to 100% N, P and K through inorganic source of plant nutrition where application of 100-50-50 kg NPK/ha could record 8.9% protein, 27.5% total amylase and 17.4% bran oil.
2.5 Effect of INM on quality parameters of potato

Kaldag et al. (2005) from a study on effect of integrated plant nutrient supply on yield, quality and nutrient uptake in okra at Rahuri, Maharashtra reported that, combined use of organic, inorganic and biofertilizers helped in accumulation of sugars in okra and the treatment also increased the mucilage content of the fruits.

Parmar et al. (2007), from the results of a study on increasing potato productivity and profitability through integrated plant nutrient system in the North-Western Himalayas reported that, combined use of synthetic fertilizers (macro and micro nutrients) along with organic manure (FYM) and biofertilizers not only increased the tuber yield as compared to farmers' practice but also had a significant effect on protein and starch content of potato tuber.

Acharya and Mondal (2007) from west Bengal reported that maximum content of ascorbic acid (14.99 mg/100g) and specific gravity(1.080) in potato was recorded in the treatment receiving 75% recommended dose of N,P and K along with 25% nitrogen through Neemtax (based on pure neem seed dried and powdered under controlled condition).

Ojha et al. (2008) conducted an experiment to study the effect of integrated use of inorganic, organic and bio-fertilizers on soil properties and the production of potato crop under alluvial soils of Allahabad, U.P. during the rabi season. Effect of inorganic fertilizers in conjunction with organic and bio-fertilizers increased all the growth parameters. Protein (2.96%) and carbohydrate (19.2%) content of tubers was the maximum in treatment receiving 120-90-75 kg N,P$_2$O$_5$K$_2$O + 30 t FYM + 12 kg Azotobacter/ha.

2.6 Effect of INM on soil fertility

The important issue related to multiple cropping is efficient fertilizer use and maintenance of soil fertility to sustain production over years. Thus, there
is a great need to increase fertilizer use efficiency and soil fertility by practicing balanced fertilization through organic and inorganic nutrients, (Singh et al., 2001). Potato is highly responsive to application of organic manures (Mondal et al., 2005). Many physical, chemical and biological limitations of soil are often associated with low levels of organic matter content in the soil. Integrated nutrient supply and management (INSM) is essential for sustaining crop productivity on long term basis. With inclusion of FYM in potato-based sequences, soil fertility was improved with balanced fertilizer application over the initial fertility status after three years, irrespective of crop rotations (Mukhopadhyay and Ray, 2000).

Chatterjee and Mondal (1996), from West Bengal reported that maximum crop productivity was achieved using 150% of the recommended doses of N, P and K in rice-potato-sesame, rice-potato-mungbean and rice-potato-groundnut systems. Yields achieved at 75% of the recommended fertilizer rate supplemented with organic manure at 10 t FYM/ha and crop residues, were at par with those obtained at 100% recommended dose of N, P and K. At harvest of 9th crop in the sequence, the total N (5-7%) and available P (14-35%) status of soil improved at recommended (100%), above recommended (150%) and below the recommended dose (75%) of fertilizer in conjunction with organic matter/manure in all the intensive cropping systems. Any reduction in the recommended dose, without compensation through organic matter/manure, depleted available K at 0-15 cm soil depth. At 150% of recommended dose, the available K status improved in 0-15 cm soil depth in rice-potato-sesame, rice-potato-mungbean and in 0-15 and 15-30 cm depths in rice-potato-groundnut system. The non-exchangeable K in 0-15 cm soil depth of rice-potato-mungbean and rice-potato-groundnut was reduced in all the treatments but the depletion was low wherever organic matter/manure or 150% recommended dose were added. Even the non-exchangeable K at 15-30 cm soil depth got depleted in all treatments in rice-potato-groundnut
system but the magnitude of depletion was less in the treatment involving organic matter/manure or 150% recommended dose, the magnitude of loss, however, was lesser than that recorded at 0-15 cm depth.

Trehan et al. (2001) from the results of an experiment conducted at Central Potato Research Station, Jalandhar, Pubjab reported that application of 30 tonnes FYM/ha to potato - wheat - rice system along with 100 kg each P and K improved the available N (from 105 ppm in control to 118 ppm), P (4.1 in control to 9.9 ppm) and K (74 to 83 ppm) content of the soil.

Khatri et al. (2002), from the results of a trial on effect of legumes on the production of potato and rice under modified cropping systems of mid-hills of Nepal reported that the incorporation of leguminous green manure resulted in improved nutrition for both rice and potato crops. Soil analysis data showed a slight decrease of pH and an increase of N, P and K content in the soil after 3 years by growing legume crops and rice. The increase in total soil nitrogen indicated that biological nitrogen fixation occurred effectively in all cropping patterns.

Kumar and Sharma (2002) from Patna reported that application of FYM + chemical nitrogen for 5 consecutive years to potato-onion-rice cropping sequence improved the organic carbon status of the soil by 20% and countered the acidification effect of urea. There was a slight improvement of P availability (6 kg/ha) in the soil, but none of the treatments could maintain the K availability of the soil at the initial level.

Chettri et al. (2004) also observed improvement in soil fertility status with integrated nutrient management in potato based cropping sequence under West Bengal condition.

Roul and Sarawgi (2005), from the results of the experiment on effect of INM on yield, N content, uptake use efficiency of rice, conducted at Raipur, Chhatisgarh reported that combined application of 100% recommended dose of
nitrogen along with 5 t FYM/ha could record significantly higher N uptake (115 kg/ha) and agronomic efficiency (0.48) as compared to inorganic sources of nitrogen alone.

Roul and Mahapatra (2006) reported that integrated use of organics and inorganic fertilizers has beneficial influence on physico-chemical properties of the soil in respect of lowering bulk density and improving the organic carbon as well as the available nutrient status of the soil in general and nitrogen in particular in rice based cropping systems.

Mohapatra et al. (2008) from West Bengal reported that there was a build up of 10.2% in total nitrogen, 6.3% available phosphorus and 3.9% available potassium in the soil compared with the initial status with the manurial treatment in which integrated use of FYM along with N, P and K after harvest of potato-jute crop sequence.

Surekha et al., (2008) from Hyderabad, Andhra Pradhesh reported higher agronomic efficiency (20.3), physiological efficiency (51.4) and recovery efficiency (39.5) of nitrogen in rice crop which received 5 t FYM and 2.5 t greengram straw/ha in potato - jute cropping system.

2.7 Effect of INM on nutrient use

From a manurial study in rice - potato groundnut sequence Sanyal et al. (1993), observed that application of FYM or crop residues in the systems enhanced (14%) uptake of nutrients.

From the results of long term rotational cum manurial experiment conducted at Central Potato Research Station, Jalandhar, Trehan et al. (2001), reported that the NPK uptake was higher in the treatments receiving combined application of FYM/green manure (Sesbania acculeata) along with
inorganic sources of P and K as compared to inorganic sources of nutrients alone in potato based cropping sequences.

Mondal and Roy (2001), from the studies of effect of potassium applied with or without sulphur and farmyard manure, on the yield and nutrient uptake by crops per annum in potato - jute - rice sequence under irrigated conditions reported that the total uptake of N, P and K by potato-jute-rice crops in sequence was maximum (297.2 kg N, 118.9 kg P and 565.1 kg K/ha per annum) in the treatment with farmyard manure along with N,P and K while that of S was maximum (51.4 kg S/ha per annum) when all the crops in sequence received S through single super phosphate along with N, P and K.

Priyadarsini and Prasad (2003) from Andhra Pradesh reported that nitrogen supply at 50% N each through fertilizer and organic sources (FYM + green manure) to rice was instrumental in recording higher nitrogen use efficiency, which was however similar to the combination of 75% N through fertilizer and 25% N through FYM + green manure. The lowest value of nitrogen use efficiency was observed with 100% nitrogen supply through inorganic sources.

Chettri et al. (2004) from West Bengal reported that combined application of 10 t FYM/ha to potato and rice along with 75% of the RDF recorded significantly higher uptake of N (242 k/ha), P (58.3 kg/ha) and K (246 kg/ha) in rice - potato - sesame cropping sequence as compared to application of 100% RD of N, P and K to rice and potato where the system uptake of N,P and K were recorded at 234, 55 and 235 kg/ha, respectively. The results supported the findings of Madhu et al. (1997).

Chettri et al. (2004), from a study on effects of integrated nutrient management on the yield of potato (cv. Kufri Jyoti) - based cropping sequences in Hooghly, West Bengal, reported that application of 125%
recommended dose of inorganic fertilizers and 75% RD of inorganic fertilizers + 10 t FYM/ha resulted in the highest N (251.7 and 242.2 kg/ha), P (62.8 and 58.3 kg/ha) and K (253.9 and 246.0 kg/ha) uptake in potato-rice system.

Khanda et al. (2005 b), from the results of an experiment conducted at Mohanpur, Nadia, West Bengal reported that rice - potato - sesame sequence recorded higher uptake of N (247.37 kg/ha) P(42.65 kg/ha) & K(322.20 kg/ha) when all the three crops received 75% RD along with 10 t FYM/ha to winter crop only.

Khanda et al. (2005 a) carried out a field experiment in West Bengal, India to assess the effects of integrated nutrient management on the nutrient uptake and yield of component crops in potato - sesame - rice, wheat - sesame-rice and mustard - sesame - rice cropping systems. The uptake of N (257 kg/ha) and K (335 kg/ha) was highest in potato-sesame-rice, whereas uptake of P (48.3 kg/ha) was highest in wheat-sesame-rice cropping system. Application of 10 tonnes FYM/ha to the winter crops could supplement 25% NPK requirement of all the component crops and increased the uptake of N, P and K by the crops. Uptake of N, P and K was improved by composite inoculums of bio-fertilizers, but was not affected by phased application of P.

From a long term manurial trial in rice - based cropping system, Stalin et al. (2006) reported that conjoined use of organic sources of nutrients i.e green manuring of Sesbania rostrata in kharif season and farm yard manure in rabi season maintained higher uptake values of all the three nutrients in rice based cropping sequences. The results corroborated the findings of Bhaskar (2003) in rice - rice system on an Inceptisol.

Acharya and Mondal (2007) from West Bengal reported that combined use of 75% recommended dose of N, P and K along with 25% N through farm yard manure to rice based cropping sequences exhibited significantly higher
percentage of potassium content in rice grain (1.386%), potato (2.898%), cabbage (0.189%) and onion (2.484%) as compared to 100% RD of NPK through inorganic only.

### 2.8 Effect of INM on nutrient balance of soil

Roy et al. (2001), from Jalandhar, Punjab, from the results of a field trial to develop an integrated nutrient management programme for a potato - sunflower - rice rotation reported that the effects of the FYM + N treatments were cumulative, especially on potato which was the most responsive crop, whereas those involving the application of NPK at 150% of the currently recommended rate were not. Also, the NPK fertility of the soil was enhanced and organic carbon content of the soil was improved following the FYM + N treatment than with NPK fertilizers applied at the currently recommended rate. Application of P resulted in a build-up of P but none of the treatments, even the applications of K to adjust for its removal, maintained the K status of the soil at its initial level.

Sharma and Sharma, (2002), from the results of field experiment conducted at the Indian Agricultural Research Institute, New Delhi, indicated that rice (Oryza sativa) - potato (Solanum tuberosum) - green gram (Vigna radiata) system removed 1060 kg N,P and K /ha. It also resulted in the negative balance of 330 kg K/ha. Nitrogen and phosphorus balance was positive in rice-potato-green gram cropping system, whereas potassium balance was negative. These results, thus, show that potassium was the most removable nutrient by the crops, which results in mining of soil K and thus calls for adequate supplementation of K.

Mohapatra et al. (2008) from West Bengal reported that soil nutrient balance after three years of potato-jute cropping system was higher in the treatments receiving inorganic fertilizers alone. Maximum (184.1 kg N, 260.4
kg P and - 62.2 kg K/ha) balance of nutrients was recorded with the treatment in which inorganic fertilizers were applied to potato crop. Combined use of FYM and inorganic fertilizers, resulted in low balance. In general potato-based crop sequences exhibited negative K balance, which could be improved with integrated use of FYM and inorganic fertilizers.

2.9 Effect of INM on economics of rice, potato and rice - potato cropping system

Balasubramaniyan (2004) from Madurai, Tamil Nadu reported that under the situations of integrated nutrient management using inorganic fertilizers (100 kg N/ha) along with green manure at 6.25 t/ha + neem cake at 250 kg/ha + Azospirillum 2 kg /ha could realize net returns of ₹10, 194/ha and benefit cost ratio of 1.62. The results are in confirmation with those of Velu and Rani Perumal (1999).

Kar (2004), from the results of a survey in the main potato-growing belt in Hoogly district, West Bengal concluded that the rice-potato-based diversified cropping system followed in the area played an important role in the rural economy in producing food crops and generating employment opportunities. Inclusion of potato in cropping system not only increased the farm productivity but also created new cold storage facilities. Balancing of N, P and K with S appears necessary for sustainable high yield and quality of the crops. Fertilizer application in the cropping cycle rather than on individual crop basis should be promoted, and the residual and cumulative effects of organic manure and fertilizers should be considered for evaluating the annual nutrient supply.

Application of 10 tonnes farmyard manure/ha to potato and rice along with 75% of the recommended dose of N, P and K resulted in lower costs of cultivation (₹59,870/ha), and higher net profit (₹79,981/ha) in potato – groundnut - rice sequence in Hoogly district of West Bengal (Chettri et al. 2004). The net production value which is the fractional unit of net profit and
cost of cultivation was also maximum (1.33) in the same treatment as compared
to that of 1.04 in the treatment receiving 100% recommended dose of N, P and K
in inorganic form. The finding confirms the results obtained by Biswas et al.
(2002) from soybean - chickpea and soybean - lentil cropping systems.

Singh and Gupta (2005) from Central Potato Research Station,
Shillong reported that application of FYM @ 15t/ha to potato along with 100%
recommended dose of nitrogen enhanced the net returns by ₹9432/ha/year.

Sarkar and Mondal (2005) from West Bengal, carried out an
investigation on effect of integrated nutrient management on the productivity
of rice - potato - soybean cropping system. The results revealed that
application of inorganic sources of plant nutrients at 150% of recommended
dose along with enmite (course neem seed + Karanja cake + other oil cakes)
at 1.35 t/ha could record highest net production value of 3.03.

Singh and Kushwah (2006), from their studies on “effect of integrated
use of organic and inorganic sources of nutrients on potato production” at
Gwalior, Madhya Pradesh reported that the net return was highest
(₹63, 627/ha) in the treatment receiving 100% NPK + 30 t FYM/ha. However,
benefit cost ratio was almost the same (2.2) under 75% NPK with 30 t FYM or
Nadep compost/ha. Hence, 25% NPK may be saved by adopting treatment
combinations comprising of 75% NPK + 30 t FYM or Nadep compost/ha.

Mohapatra et al. (2008) reported that to get maximum productivity
(23.77 t/ha of tuber and 4.18 t/ha of fibre), and profitability (₹48, 580/ha) from
a potato - jute cropping sequence under West Bengal condition, the crop
should be manured with integrated use of N, P and K and FYM to potato,
followed by 40 kg N + 8.8 kg P + 16.6 kg K/ha to jute crop. The total cost of
cultivation was around ₹40, 000/ha with returns per rupee invested at 2.21 in
the same treatment.
Natarajan et al. (2008) from the studies on “influence of organic and inorganic nitrogenous fertilization on growth, yield and economics of transplanted rice” in Tamil Nadu, reported that application of 50% N as Sesbania aculeata + 50% N through inorganic fertilizers yielded higher net return and benefit cost ratio of ₹60,591/ha and 2.90, respectively.

Application of inorganic fertilizers alone year after year not only has deleterious effect on soil but also has negative impact on the quality of produce. In most of the rice based cropping systems, the removal of nutrients often exceeds the amount of nutrients applied (Acharya and Mondal, 2007).

In spite of several sound recommendations, farmers apply fertilizers in their own way mostly with more amount of nitrogenous fertilizer than P and K, at times even without P and K. To have a balanced fertilizer schedule it is advised to adopt simultaneous use of organic, inorganic and bio-fertilizers to sustain the system productivity of various crop sequences as well as to maintain the soil fertility and productivity. The present investigation is aimed to work out judicious combination of organic, inorganic and bio-fertilizers for rice - potato cropping sequence under irrigated tracts of Coastal Orissa which not only will increase the system productivity but also takes care of soil health and quality of produce.