REVIEW OF LITERATURE
2.0 REVIEW OF LITERATURE

A short review of literature regarding long-term experiments on fertilizer use and cropping in different parts of the world is being presented under the following broad headings.

2.1. Effect of Continuous Cropping and Manuring on the Performance of Crop Yields

It is an accepted fact that growing practice of same crop (monoculture) in the same plot year after year affording best possible management practices brings down the yield performance of crops (Blair and Prince 1936; Smith 1942; Wright et al. 1950; Obokoto & Stephens 1963; Gomez 1968; Mereik 1969; Anderson & Peterson 1973) and cropping practices without manuring deteriorate the productivity level of the soil which cannot be checked simply by following the crop rotation alone. To sustain such crop production at a satisfactory level in a long way it is required to follow a suitable crop rotation in combination with balanced application of fertilizers and manures (Cooke et al. 1968; Jegorov 1968; Balla 1963; Ghosh & Kanzaria 1964; Ozaki 1964; Garuchev 1967; Schumaker et al. 1967; Rahaja et al. 1971; Dospokhov 1972; Reichbuch & Hera 1972). Inclusion of leguminous crops in the cropping pattern generally tends to improve or at least maintains the level of yield production (Seshadri 1964; Sen 1963; Mann & Gandhi 1964; Singh 1967; Singh et al. 1972).
From the analysis of the results of the past manurial experiments in India, Vaidyanathan (1933) observed that application of ammonium sulphate or sodium nitrate in different types of soil for several years gave much lower yields of cotton and other crops than with nitrogen plus phosphate treatments. Continuous application of nitrogenous fertilizers alone resulted in moderate to appreciable decrease in yield of rice, wheat, maize, oats and barley (Caldwell 1957; Digar 1958; Prasad et al. 1971; Maurya & Ghosh 1972; Anderson and Peterson 1973). On the other hand, Banerjea et al. (1971) observed a quite effective result obtained from the application of nitrogenous fertilizers alone in the studies of long-term fertilizer-cum-crop rotation with maize, jowar (Sorghum) and wheat. Similar findings were also obtained by Warren et al. (1958), Prasher and Singh (1963), Latkovics and Kramer (1968), Tucker et al. (1971) and Powell & Webb (1972). Presumably, in such cases, soils did not become limiting in respect of availability of essential elements required for crop growth.

Significantly better yields of cereals and other non-legumes have been obtained due to single application of phosphatic fertilizers than either nitrogen or potassium, when averaged over long periods (Sanyasi Raju 1952; Warren 1956; Caldwell 1957; Maurya & Ghosh 1972). In most of the cases a combination of phosphate with nitrogen showed better than either of them...
alone (Ghosh & Kanzaria 1964; Sekhon et al. 1966; Singh et al. 1966; Spratt 1966; Campbell & Brown 1966; Shumaker et al. 1967; Haeischbuch et al. 1970) and Prasad et al. 1971). The average yield of maize over 20 years in the permanent manurial experiments conducted at Pusa showed no significant response to potassic fertilizer in the soils containing about 140 kg/ha of available K2O (Sen & Kavitkar 1960). Corn grown continuously for 13 years in a silty loam soil did not show any benefit from potassic treatment though the soil contained only 0.29 and 0.22 mg. of available K/100 g of soil in the layers of 0 to 20 and 20 to 40 cm depths respectively (Lute & Jones 1969). While an absence of response has featured in several long-range experiments (Vaidyanathan 1933; Sethi et al. 1952; Shinde & Ghosh 1971; Randhawa 1973) there have been also many instances which showed moderate to slight increase in yield due to potassic fertilization (Stewart 1947; Sanyasi Raju 1952; Caldwell 1957; Ghosh & Kanzaria 1964; Shing & Chang 1964; Gorbunova 1965; Chayman & Mason 1969 and Cooke 1970). During recent years the use of potassic fertilizers proved convincing and economic response at several centers particularly when higher yield levels are attained by growing fertilizer responsive varieties with adequate dressing of nitrogen and phosphatic fertilizers. The crops like potato and high-yielding varieties of wheat, rice, bajra (pearl millet) and maize showed a response to potassium applied over a basal dose of nitrogen and phosphorus.
in a number of district trials conducted for at least three years (Raheja et al. 1970; Prasad & Mahapatra 1970). Significant contribution in respect of improving soil productivity through the role of bulky organic manure has been established on long-term experimentation all over the world and a special reference may be made of the tropical and sub-tropical countries (Kalamkar & Sripral Singh 1935; Basu & Kibe 1943; Crowther 1948; Wright et al. 1950; Djokoto & Stephens 1961; Miller 1963; Sundara Rao & Anoop Krishan 1963; Tisdale & Nelson 1966; Cooke 1970; Maurya & Ghosh 1972). The experimental results critically evaluated by Vishwa Nath (1931) from the use of inorganic fertilizers applied in permanent experiments at Coimbatore proved better yield response than farmyard manure during the first thirty six cropings but at the later stage the superiority of bulky organic manure manifested quite evidence for the 37th to 56th crops. The evidences confirmed on the use of balanced combinations of chemical fertilizers showing equally effective and sustaining production over long periods have also been put forth (Russell & Watson 1940; Caldwell 1957; Digar 1958; Balls 1963; Gorbunova 1965 and Cooke 1970).

The average production of cereals over eight years manifested an increase by 23 per cent due to dung applied once in every four years @ 40 tonnes/hectare, 24 per cent by mineral NP fertilizer in amounts equal to those in the organic manure, and 21 per cent by half NP fertilizer through dung plus half NP fertilizer through mineral

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fertilizers (Czuba 1967). Nearly comparable yields of wheat have been obtained by Reichbuch and Hera (1972) with the use of 120 kg N, 80 kg P$_2$O$_5$ and 80 kg K$_2$O/ha or half the dose of N and P along with 20 tonnes of FM once in a year. In several cases best results are obtained from a combined application of organic manures and chemical fertilizers (Vishwa Nath 1931; Smith et al. 1955; Patel et al. 1963; Dospékhov 1972; Specht 1972; Krishnamoorthy and Ravikumar 1973).

Several reports of recent studies on soil application of Zn @ 5 to 20 kg ZnSO$_4$/ha showed a marked increase in grain yield of high yielding varieties of wheat (Mehta 1969; Mahapatra et al. 1970; Randhawa 1970; Takkar et al. 1971), maize (Gautam et al. 1964; Gupta and Ram 1967), rice (Venkateswarlu 1971; Singh et al. 1972) and bajra (Randhawa 1969). Zinc response to pulses was observed in a few cases (Mathur et al. 1969; Saxena & Singh 1970). Zinc sulphate applied before rabi (winter) season in a series of rotational trials at Ludhiana brought about a significant increase in the yield of all kharif (monsoon) crops (Randhawa 1974).

At the same time many instances could show no perceptible influence of zinc application. Zinc applied in experiments extending over four years on alluvial soil tract of Delhi has failed to manifest any beneficial effect on oats, maize, peas, gram and soybean (Ghosh et al. 1964). Same was the case with
Results emanating from the four-year field experiments conducted at major soil types of 10 different centres all over the country under the All India Coordinated Project on Long Term Fertilizer Experiments, have revealed that out of 25 tests (rice, wheat, maize, bajra, cowpea and soybean), a significant response to zinc was found in one experiment each on rice and soybean (Ghosh 1975).

As legumes have a high requirement of sulphur, a profitable response to this nutrient has generally been observed in these crops. An experiment carried out by Dalal et al. (1963) on groundnut production showed an increase in yield by 34 per cent over control with ammonium sulphate as against 46 and 41 per cent with superphosphate and gypsum, respectively, indicating hereby that the response was more than what could be attributed to N, P or Ca content of fertilizers. An application of NPK fertilizers incorporating about 200 kg of sulphur in soil/ha yielded an additional 20 per cent of groundnut production over the same level of NPK nutrients made from non-bearing sulphur sources (Kanwar & Chopra 1966). Profitable effect of sulphur has been reported in pea (Rao & Das 1967), mustard (Singh et al. 1970), berseem (Verma 1972), red clover (Robertson & Yuan 1973), sweet corn (Daigger & Fox 1971) and subterranean clover (Jones and Euchman 1973). In a cycle of
rice – wheat rotation followed by onion and maize on an alluvial
sandy clay loam soil no effect of sulphur on the yield of rice
and wheat upto fifth and sixth crops was observed by Das &
Datta (1973), but the succeeding crops of onion and maize gave
significant response.

2.2 Nutrient Composition of Crops as Affected by Rotational
Cropping and Use of Manures and Fertilizers

Since not enough information regarding the long-term
effect of intensive cropping and manuring on the nutrient
composition of crops are recorded, the results of studies conduc-
ted for relatively shorter periods are reviewed.

Enough information would clearly indicate that
application of nitrogen increases its concentration in wheat
(Ghosh & Kansaria 1964; Bhargava & Motiramani 1967; Fuehring
1969; Chandravanshi & Singh 1972; Gasser & Thorburn 1972;
Khetawat et al. 1972; Tucker & Baker 1972), corn (Shukla 1972;
Powell & Webb 1974), sorghum (Lowell et al. 1964), swedes,
oats and barley (Keith 1964) and jute (Annual Report 1962-63).
However, as reported by Singh (1963) ammonium sulphate decreased
the nitrogen content in wheat while Markus (1965) did not find
any influence of nitrogen on crop composition. Fertilizer
nitrogen did not significantly affect the percentage content of
P and K in the plant (Bhargava & Motiramani 1967; Kashirad
& Bazargani 1972; Khetawat et al. 1972) but in some cases
increasing rates of N raised the concentration of P & K in
wheat (Gasser & Thorburn 1972) and of P in corn (Lutz et al. 1972). Thomson (1962) found that nitrogen level applied to maize improved the contents of N, Ca, Mg, Mn, Cu and Zn and depressed the content of K. Khanna (1964) reported that on a slightly alkaline soil, urea was found to enhance the percentage content of N and Ca but not of P in bajra (pearl millet) grain. N application (up to 90 kg/ha) increased the concentration of Mg and Mn, as observed by Shukla & Bhatia (1971).

Phosphorus concentration in plants is generally enhanced significantly with the use of phosphatic fertilization and more so with higher doses (Burlesson et al. 1961; Ekdahl et al. 1964; Singh & Jain 1968; Kandera 1972; Robertson & Yuan 1973; Powell and Webb 1974). Beneficial influence of repeated dressing with phosphorus fertilizers on the nitrogen composition of cereals was reported by (Singh & Jain 1968); and Andrew & Robins (1969). Shargava & Motiramani (1967) observed that the use of superphosphate significantly decreased the concentration of N & K but increased that of Ca & Mg in wheat. Its use on a long-term basis resulted in higher content of Ca and a considerable reduction in potassium concentration in the plant (Dey 1971). Annual dressing with P showed no significant effect on K, Mg, Zn and Cu concentration but increased the content of Mn (Robertson & Yuan 1973). Increasing rates of P significantly raised the concentration of Mn in the grain, decreased that of Zn and did not affect Cu (Prohaszka
Depression of Zn concentration in plants due to phosphorus application has been reported by several workers in their experiments (Brown & Krantz 1966; Shukla & Morris 1967; Mehta 1969; Warnock 1970; Lessman & Ellis 1971).

It is generally agreed that potassium content in plants goes up with its application (Boswell & Parks 1957; Thomson 1962; Mercik 1969; Lutz et al. 1972; Goralski & Mercik 1973; Landua et al. 1973; Lutz et al. 1974) while Milcheva (1965) showed that even high doses of K (80-320 kg K/ha) did not materially affect the K concentration of cereal grains irrespective of soil type and available soil K. High levels of potassium adversely depressed the concentration of N & P. It was reported by several workers that potash fertilization markedly depressed the concentration of Mg (Boswell & Parks 1957; Fred & Henderson 1962; Thompson 1962; Goralski & Mercik 1973; Landua et al. 1973) and also of Ca in the plant (Thompson 1962; Boswell & Parks 1957). An adverse influence on the concentration of Mn & Zn was recorded by Thompson (1962). The study has been carried out hardly relating to sulphur composition. Tucker and Baker (1972) observed no effective influence on the concentration of sulphur in grain and straw of wheat due to continuous use of potassium.

Karpova (1965) obtained an increase in the percentage contents of N, P and K in all the crops using a systematic application of NPK fertilizers in increasing doses in an
intensive crop rotation. Kuznetsova (1965) observed that HPK improved the concentration of N in the grain and straw of wheat. Goncharenko (1966) observed that phosphorus alone did not necessarily enhance the percentage of P in maize plants but N plus P treatment always decreased the content of both the nutrients. In comparison to the combined treatment of NP, the treatment NPK usually decreased the contents of P and N but increased that of K. According to Gupta & Das (1962) both NPK and NP treatments increased and FM decreased the Ca composition of maize grain. With the treatments of PK and NPK the concentration of Fe was found to be somewhat higher. After about four decades of fertilization without potassium (NP), percentage of N in plants was marked distinctly higher and lower when fertilization without phosphorus (NK) was practiced as compared to full mineral fertilization (NPK). Mercik (1969) recorded the minimum concentration of Ca without potassium (NF) and the lowest Mg content with NPK, PK and NK treatments.

Zinc application significantly increased its concentration in the test crops (Brown & McCormick 1971; Padhiyar et al. 1972; Coffman & Miller 1973; Randhawa 1974). Zinc depressed the concentration of N and P in wheat (Sambooramaran et al. 1968) and appeared to have a beneficial effect on nitrogen in maize but in combination with phosphorus it decreased the N content as compared to Zn alone (Mehta 1969). Zinc has no
Sulphur application increased its percentage content in cotton, clover, tobacco and Bermuda grass (Jordan & Bardsley 1958), lucerne and maize (Caldwell et al. 1969), soybean and white clover (Robertson & Yuan 1973). According to Caldwell et al. (1969) with increasing levels of sulphur nitrogen content of lucerne was found to be higher but there was a fall of P concentration. On the other hand, Kashirad & Bazargani (1972) marked a decline in nitrogen concentration while Brown et al. (1974) did not observe any influence of sulphur use on nitrogen and sulphur composition of wheat.

The application of sulphur had no significant effect on the concentration of K, Ca, Mg and Zn in lucerne, maize (Caldwell et al. 1969), soybean and white clover (Robertson & Yuan 1973). A significant influence of sulphur on the content of Mn but not of Cu has also been shown by Robertson & Yuan (1973).

2.3 Uptake of Nutrients in Crops as Influenced by Intensive Cropping and Manuring Practices

In the classical experiments conducted at Pusa, nitrogen treatment was invariably associated with the greater uptake in wheat and other crops while potassium has a depressing effect. Higher uptake of both N and P was noted.
in their combined application. F7M was observed to be the leading to the higher uptake of N in wheat and barley (Sinha 1957). According to Puntamkar et al. (1965) and Rhetawat et al. (1972) increasing levels of nitrogen enhanced the uptake of N as well as P and K. Many findings are in support of significant increase in the uptake of N as well as a result of phosphorous application (Burleson et al. 1961, and Gupta et al. 1969). Singh (1963) recorded that higher doses of phosphate markedly improved the crop uptake of both N and P. No difference of N and P uptake in NF and NP treated plots was obtained by Ansorge (1963) but the total K removed by the crops was substantially lower under the former treatment.

Nitrogen enhanced the uptake of Zn in a number of situations (Viets et al. 1957; Singh & Tripathi 1975). Mandal and Sinha (1964) obtained a significant effect of NPK treatment on the manganese uptake in several crops like moong (Phaseolus aureus), soybean, ground-nut and cotton.

Several workers (Thompson 1962, Beaman & Leggett 1964 and Gupta et al. 1969) observed that application of P adversely affects the uptake of Zn. Many workers have interpreted this observation on the basis of precipitation of Zn phosphate which appears to be untenable due to the fact that zinc added to the phosphatic fertilizers is not reduced in availability. According to the views of Burleson and Page (1967) the interaction
of P and Zn occurs at the root surface and or in root cells with associated inhibition of Zn translocation from roots to tops as the phosphorus uptake increased.

Mulder and Gerrets (1952) and Gupta et al. (1969) reported that the addition of phosphatic fertilizers especially to acid soil improved the uptake of Mn whereas Datta Biswas (1964) observed that uptake of Mn by forage was suppressed due to superphosphate application and similar findings was reported by Baser and Ram Deo (1967) in case of jowar. In a number of field crops the uptake of copper has been reported to suffer due to heavy doses of phosphorus application (Baser & Ram Deo 1967 and Gupta et al. 1969). Datta Biswas (1964) reported that uptake of copper in forage was higher with nitrogen and phosphorus application than with potassium treatments.

Weare and Patterson (1966) observed that a heavy dose of potassium enhanced the zinc uptake in sorghum plants but in the presence of phosphate dressing potassium had no effect. Aiyer (1948) reported that manganese uptake by rice was not altered by the presence or absence of potassium whereas there was a definite increase in the iron uptake in straw in the absence of potassium fertilizer.

The role of bulky organic manure in increasing the uptake of major nutrients by the test crops has been conclusively established in most of the classical manurial experiments.
(Patterson & Watson 1960; Adams 1962 and Ghosh & Kanzaria 1964) have conclusively established in most of the classical manural experiments (Atkinson et al. 1958 and Sekhon 1974). Grunnes et al. (1961) reported higher uptake of zinc in corn from a deficiency level due to application of 20 t/ha of FM.

From an interesting study carried out by Beyers et al. (1969) it appeared that the application of zinc to zinc-deficient plots could significantly enhance the crop uptake of P, Cu, Fe and Mn whereas the adjacent plots having adequate levels of available zinc showed no such effect. Meishri and Mehta (1971) observed that total uptake of zinc, N, P, K and Mg was increased with zinc application but the total uptake of Fe, Mn, Cu and Ca remained unchanged.

The sulphur requirement of many crops is about the same as that of phosphorus. Legumes and cruciferous plants take relatively higher amounts of sulphur than cereals (Williams & Steinbergs 1959). Application of sulphur in combination of NPK (NPKS) significantly increased the uptake of sulphur and also of nitrogen, phosphorus and potassium by bermum (Chopra & Kanwar 1966). However, with the increasing dose of sulphur higher uptake of sulphur has been recorded. Sulphur has been found to promote the uptake of nitrogen by pea (Rao & Das 1967), white clover (Spencer 1959) and soybean.
(Robertson & Yuan 1973). Sengupta and Cornfield (1964) recorded an increase of phosphorus uptake in corn due to application of sulphur. Soybean and mustard also showed a considerable uptake of native soil sulphur due to application of sulphur (Pasricha & Randawa 1973).

2.4 Soil Characteristics as Influenced by Intensive Cropping and Manuring

2.4.1 Organic Matter

The practice of cropping year after year without adequate addition of manuring would invariably result in a fast depletion of organic matter content of the soil (Pur 1945; Dodge & Jones 1948; Hobbs & Brown 1965 and More & Quantin 1972). Although the favourable effect of crop rotation with the inclusion of legumes has been duly stressed (Sundara Rao & Anoop Krishan 1963; Biswas et al. 1967; Havangi & Mann 1970; Sahu 1972; Nair et al. 1973), but it has been felt that rotation alone may not be enough. Increase of soil organic matter with the use of manures and fertilizer maintenance in soil has been reported by (Russell and Watson 1940; Pur 1945; Acharya & Rajagopal 1956; Cooke et al. 1958; Ghosh & Kansaria 1964; Peavy & Greig 1972 and Bavaskar & Zende 1973). Regarding the effect of nitrogenous fertilizer alone Scharf (1967) reported that after 14 years the soil experienced a small increase in organic carbon. In some experiments conducted in this country (Mandal & Pain 1965 and Choudhry & Vachhani 1965) the continuous use of ammonium sulphate for several years did not affect the organic carbon.
and total nitrogen status in soil or even resulted in a decline in organic carbon (Prasad et al. 1971). The beneficial influence of phosphate fertilization in fodder legumes in building up of organic carbon levels has been highlighted by Patel et al. (1963) and Biswas et al. (1967). Sinha (1957) reported that combined application of nitrogenous and phosphatic fertilizers in soil could maintain the soil organic status as effectively as FM, green manure, and oil cake. On the other hand, Acharya and Rajgopalan (1956) and Pal (1974) did not observe any improvement in respect of organic matter and nitrogen content in soil due to the use of chemical fertilizers. The role of bulky organic manures in raising the organic matter status in soil has been largely indicated inspite of its rapid destruction in tropical climate (Russell 1961; Ghosh & Kansaria 1964; Biswas & Joshi 1971; Sahu & Nayak 1971; Shinde & Ghosh 1971). Cooke et al. (1958) reported that after 56 years of continuous manuring, the plots under FM treatments contained one and half times as much carbon as those plots receiving inorganic fertilizers. However, Young et al. (1960) observed that 40 years of cropping depleted the organic carbon status even in manured plots (by about 20 per cent), but of course to a lesser extent than with NPK fertilizers. After 38 years of FM application the organic carbon percentage in soil was greater by about 0.2 units than that obtained from NPK fertilized plots (Peavy & Gregg 1972). While highest level of
organic matter was produced due to dung application, the second best results were obtained with NP or NPK fertilizers (Taha et al. 1966). Evaluating the cumulative effect of NPK and dung in an intensive rotation followed for 50 years, Lykov (1963) concluded that though much of the loss in organic matter could be checked with NPK fertilizers an increase was only possible with the use of dung preferably with fertilizers.

2.4.2 Soil Nitrogen (Total and Available)

Since soil nitrogen maintains some sort of equilibrium with organic carbon, there is also fast depletion with unmanured cropping and addition of manures and fertilizers either maintains or raises the nitrogen level (Russell & Watson 1940; Ghosh & Kanzaaria 1964; Sundara Rao & Anoop Krishan 1963; Spratt 1966 and Bavaskar & Zende 1973). Little or no improvement of total nitrogen content in soil may be obtained through single application of fertilizer nitrogen over a long period (Puhr 1945; Merick 1962; Sahu & Nayak 1971 and Maurya & Ghosh 1972) but there may be noticeable increase in the amount of mineral - $N$ (by 12-25%). Sundara Rao and Anoop Krishan (1963) in a study of continuous use of ammonium sulphate plus superphosphate with or without potash recorded a small decrease in soil nitrogen by 10 to 15 per cent. Sinha and Prasad (1980) in a study of long-term manure and fertilizer application observed that in most of the treatments the net gain in soil $N$ was
lower with lower dose of fertilizer application. FM proved effective in several long-term experiments in influencing the nitrogen level of soil than mineral NPK fertilizers though not always to a significant extent (Cooke et al. 1958; Bishop et al. 1964; Osipova 1964; Ghosh & Kanzaria 1964; Johnston 1969; Sahu & Nayak 1971; Maurya & Ghosh 1972 and Peavy & Greig 1972). Results from the permanent manural experiments conducted at Coimbatore have indicated that with NPK application the total nitrogen in the soil was maintained at the same level as with cattle manure (Krishnamoorthy & Ravikumar 1973). Mercik (1962) found that plots under sandy loam soil types having received P & K only for 39 years contained the same level of available N as those plots fertilized with all basic nutrient components (NPK). In comparison, relatively large dressing with FM considerably raised the available nitrogen as well as organic matter and total nitrogen. The available nitrogen in the plough depth showed a significant increase with compost and cow dung application (Hashimoto et al. 1971) but not with ammonium sulphate (Mandal & Pain 1965). Nair et al. (1973) recorded an improvement in available N content with the growing of leguminous crops in a multiple cropping system.

4.2.3 C/N Ratio:

Acharya and Basopalan (1956); Digar (1958); Ghosh & Kanzaria (1964) and Yamamoto et al. (1966) found that repeated
dressing with FIM contributed mainly towards organic carbon in soil to the extent of 20 to 50% over control plots than in respect of soil nitrogen, as a result of which the C/N ratio gets widened. On the other hand, in most of the cases there is a narrowing down of the C/N ratio without any manuring or with the use of chemical fertilizers only. Sinde and Ghosh (1971) observed a significant decrease of C/N ratio due to superphosphate application at the level of higher doses over a decade. However, intensive use of manuring and fertilizers for 40 years brought no change in C/N ratio (Young et al. 1960).

4.2.4 Phosphorus Status (Total and Available)

It is the general view that continuous cropping invariably resulted in a depletion in total soil P, but with manuring as well as phosphatic fertilization it was either maintained at the original level or even increased (Russell & Watson 1940; Cooke et al. 1958; Hays et al. 1961; Mattingley 1966; Bailey 1967; and Anderson 1970). Puhar (1945), Fredrikson (1958), Ghosh and Kanzaria (1964), Peck et al. (1965), Bailey (1967), Intz & Jones (1971), Maurya and Ghosh (1972) and Goralski & Mercik (1973) reported that a systematic application of phosphatic fertilizers favorably influenced the available P in soil. Rao & Sharma (1978) reported that increasing level of phosphorus fertilizer application led to a greater increase in the available P content of the soil. Ridley & Hedlin (1962) and Young et al. (1960) obtained a
marked increase in available soil P after 38 to 40 years due to an even dose of 13 to 19 ppm P applied once in every four years. Continuous application of ammonium sulphate alone markedly lowered the available phosphorus status of the soil (Prasad et al. 1971; Sahni & Nayak 1971; Maurya & Ghosh 1972). Kanwar & Prihar (1968) observed that ammonium phosphate built up the phosphorus status of the soil more effectively than FYM in the long-range memorial trials at Sonepat, Hansi and Jallandhar. The application of NP fertilizers and FYM over a nine years period in an experiment under dry land condition resulted in a significant increase in soil available P as compared to control (Havanji & Mann 1970). A marked improvement in available P level was recorded by Pal (1974) after regular application of NPK fertilizers to six crops in a rotation of maize and wheat. Phosphate fertilization in legume crops in rotation significantly raised the available phosphate status of the soil (Patel et al. 1963 and Biswas et al. 1977).

It has become a common observation that the available P status in soil goes up due to large amount of bulky manures and more so with phosphate treatment (Namu & Kibe 1943; Caldwell 1967; Bishop et al. 1964; Osipova 1964; Karpova & Petrova 1966; Pichot 1971 and Sandhu & Meelu 1974). Lowest value of available phosphorus was recorded from the plots receiving only nitrogenous fertilizer (Prasad et al. 1971), and the organic manure supplemented by chemical fertilizers resulted in highest content of
available phosphorus. According to Hashirod (1972), sulphur could be used to enhance the availability of soil P in alkaline or calcareous soils, the effect being closely connected with the fall of soil pH.

2.4.5. Soil Potassium (Total and Available)

Significant changes in the total K content of the soil were not obtained due to continuous cropping and moderate application of potash fertilization (Blair & Prince 1936; Ghosh & Kansaria 1964; Lenz 1968 and Ghosh & Ghosh 1971). The results of the experiments conducted by Krishnamorthy and Ravikumar (1963) in Coimbatore showed a marked increase in total K in NPK plots as against cattle manure treatment. Fertilizer dressing without K for 4 to 5 years considerably decreased K content in the soil (Czuba 1967). Zurn (1964) recorded a considerable decrease of K (total and available) unless higher rates of P & K were used, from a field test extending over 10 years under intensive cultivation of fodder crops.

Regular incorporation of potassium has quite often significantly increased the K content of the soil (Maclean & Doyle 1963; Ghosh & Kansaria 1964; Peck et al. 1965; Vittum et al. 1968; Saha & Nayak 1971; Goralski & Marcik 1973; Lutz 1973 and Pal 1974). Prudnikov (1980) observed that an application of potash @ 80 kg/ha of K2O in the combination of NK, PK or NPK on a дернo-podzolic loamy soil increased the content of water-soluble and exchangeable forms of potassium in the soil.
However, Findlay (1973) obtained a small increase in K after annual addition of K fertilization to sandy soil of low and medium fertility for seven years. Garbouchev (1966) reported that available P & K statuses fall to a lower level with NPK than PK treated plots due to better growth and higher crop removal in NPK plots which was induced by nitrogen. In a long-term trial an addition of 25 t/ha of PNM could result in a considerable rise in available P & K as compared to mineral NPK only (Langinow & Kaszubiak 1964). Lutz and Jones (1971) observed a rapid initial decrease of available K from an experiment conducted for 10 years without potassium or low dose of K (0, 23 & 46 t/ha) and 50 percent depletion took place at the end of the study even at the higher dose.

2.4.6 Sulphur Status

More than 90 percent of sulphur may be present in organic form in temperate regions but in many Indian soils organic sulphur is as low as 20 percent of the total (Ahmed Jha 1969). Kanwar & Mohan (1964) obtained about 242 and 159 ppm of total sulphur in acid and alkaline soils respectively, in Punjab and Haryana States. According to Nicholson (1970) substantial quantities of sulphur may be lost from the soil and soil plant system.

As stated by Williams & Steinbergs (1969) that soil should contain at least 10 ppm of sulphate sulphur for normal plant growth. Sulphur deficiency is more likely to take
place in heavily drained sandy soils under condition of high rainfall. Intensive cropping with the application of non-sulphur bearing fertilizers (urea, ammonium nitrate, triple superphosphate etc.) commonly causes the deficiency of sulphur in plants.

The amounts of sulphur extractable with potassium dihydrogen phosphate were reflected in plant uptake. The quantity of sulphur mineralized from soil organic matter was insufficient for the plant growth with an adequate supply of nitrogen (Cowling & Jones 1970). Increased forage yields under legume cultivation resulted in rapid decrease in water-extractable sulphate in soil (Walker & Doornenbal, 1972).

2.5 Soil Reaction

Due to repeated use of ammonium sulphate, soils very often become acidic adversely affecting the crop growth (Russell 1961; Tisdale & Nelson 1966; Mandal & Pain 1966 and Prasad et al. 1971). On this aspect Kanwar & Prihar (1962), Chandhry & Vachhani (1965), Sahi & Nayak (1971) and Shinde & Ghosh (1971) found no deleterious effect on soil reaction due to long use of ammonium sulphate provided soil contained adequate amount of calcium status. Taha et al. (1966) reported a decrease in pH as influenced by use of organic manure while Kanwar & Prihar (1962) and Shinde & Ghosh (1971) did not observe any such effect.
In general a negligible influence of superphosphate and potassic fertilizers (sulphate or chloride) on soil reaction has been observed \cite{wright1960, russell1961, patel1963, tisdale1966} even after their use for many years.

2.5.1. Cation Exchange Capacity & Exchangeable Bases

Wright et al. \cite{wright1960}, Kanwar & Prihar \cite{kanwar1962}, Mandal & Pain \cite{mandal1965}, Grant \cite{grant1967}, Bache & Heathcote \cite{bache1969}, Hashimoto et al. \cite{hashimoto1971} and Sabu & Nayak \cite{Sabu1971} observed that the prolonged use of bulky organic manures exerted a favourable influence on the cation exchange capacity (CEC) of the soil. But Patel et al. \cite{patel1963} and Shinde & Ghosh \cite{shinde1971} did not observe any significant effect of FIM and inorganic fertilizer on CEC.

Jegorov \cite{jegorov1968} reported that the inorganic fertilizer (NPK) which improved the soil fertility also increased the cation exchange capacity in the long run. According to the findings made by Wright et al. \cite{wright1960}, Digar \cite{digar1968}, Mandal & Pain \cite{mandal1965} and Bache & Heathcote \cite{bache1969} continuous application of ammonium sulphate either reduced or did not affect the cation exchange capacity of soil.

Russell & Watson \cite{russell1940}, Cooke et al. \cite{cooke1958}, Karpova & Petrova \cite{karpova1966} and Peary & Greig \cite{peary1972} observed the favourable effect of potassium fertilizers on the exchangeable K-status of the soil while the exchangeable K went down sharply in absence of potash fertilizers. But, it remained constant with manure.
and increased under manure plus potash treatment (Heick & Dorph - Peterson 1960). As reported by Hurbeta et al. (1947) and Kamwar & Prihar (1962) that FYM increased the exchangeable K only after a prolonged use. Regular use of FYM for many years resulted in increasing trend of cation exchange capacity and exchangeable Ca & K and decreasing trend of exchangeable Na (Yamashita 1967). Ammonium sulphate used for long time is known to decrease the exchangeable Ca (Chang & Chu 1960; Kamwar & Priha 1962; Mandal & Pain 1965; Jakobiec 1966 and Bache & Heathcote 1969). However, Shikla (1972) obtained a significant rise in exchangeable Ca, Mg & K due to the use of nitrogenous fertilizers. Gorgalski & Mercik (1973) reported that the increase in exchangeable K due to the use of potassic fertilizer in heavy rates resulted in fall of exchangeable Mg upto a deficiency level. Chang & Chu (1960) reported that the use of superphosphate or FYM in alluvial clay loam enhanced the exchangeable Ca. The use of FYM resulted in raising the status of exchangeable Mg while green manuring. NPK and N alone had somewhat depressing effect. While the basal dressing with cattle manure used in the Coimbatore experiment (Soundarajan 1962) increased the CEC of soils, the use of NPK fertilizers depressed the exchangeable Ca and did not affect exchangeable K. As a result of long term manuring and cropping any appreciable change in the content of exchangeable bases was not observed by Shinde & Ghosh (1971) and Maurya & Ghosh (1972).
2.6 Micronutrient Availability as Affected by Cropping and Manuring

As a result of using high-yielding varieties and high-analysis fertilizers in the system of intensive cropping practices, the depletion of micronutrients not added through fertilizers takes place more rapidly. As the need for higher crop yield rises up and plants requirements for its major nutrients are adjusted efficiently through applied fertilizers, micronutrient status in soil not replenished externally likely becomes limiting.

2.6.1. Zinc

According to Kanwar & Randhawa (1967) among the micronutrients zinc deficiencies are found more widely in the field and fruit crops in different parts of India. Inspire of this, no adequate attention has not given so far to determine zinc depletion pattern under intensive cropping and manuring.

Mineral soils contain the total zinc varying between 10 & 300 ppm (Swaine 1955). Depending upon the extractant materials used for determination of available zinc in soil, the Indian soils have been reported by Kanwar and Randhawa (1967) to contain available zinc status ranging from less than 1 ppm to a few ppm. The critical levels of zinc deficiency as determined by different extraction with 0.1 N HCl (Wear & Somers 1947), dithizone (Brown et al. 1962) and diethylene triamine pentaacetic acid (Lindsay & Norvell 1969) have been found set at 1.0, 0.5 and 0.55 ppm respectively.
Zinc deficiencies usually occur in soils having pH greater than 6.0 and lower values of available zinc have been obtained at higher soil pH (Nair & Mehta 1959; Sharma & Motiramani 1969). As reported by Nair & Mehta (1959), Hodgson et al. (1967) and Sharma & Motiramani (1969), that organic matter increased the available zinc status in soil. In contrast Jones et al. (1936), Camp (1940) and Tiwari & Mishra (1964) reported that soil organic matter and its addition to soil decreased the available zinc status in soil.

Nowosielska (1966) in his studies with long-term manuring and fertilization observed that available zinc went up to 19 ppm in the soil manured with increasing doses of dung upto 60 t/ha as compared to 5 to 6 ppm of available zinc in the soil where mineral fertilizers were applied. Grunes et al. (1961) reported that zinc deficiency could be reclaimed by the addition of 20 t of FYM/ha which supplied about 1 kg of zinc.

Prasad et al. (1968), Sharma et al. (1968) and Badarur & Venkata Rao (1973) observed a noticeable decrease in available zinc in the soil due to phosphate fertilization. According to Warnock (1970) extractable zinc was not affected by phosphate treatment. Bowm et al. (1960) showed that addition of 4.5 kg/ha of zinc for 4 years was rarely detectable above the unfertilized plots. It was also observed by Fullett & Lindsay (1971) that applied fertilizer zinc declined to 44 percent of its initial value after cropping and fertilization.
2.5.2. Manganese

Biswas (1953) and Biswas & Gawande (1964) have reported that total manganese in Indian soils is to be ranged from 92 to 11,500 ppm and majority of soils contains 300 to 1600 ppm of Mn. Available manganese consists of water-soluble, exchangeable, reducible and active forms. According to Steenbjerg (1935) 3 ppm of exchangeable Mn was the critical limit in soil but this was revised by Toth (1951) to 5 ppm. Jones and Leeper (1951) considered that healthy soils should contain 20 to 50 ppm of active manganese. Kanwar and Randhawa (1967) fixed the limit of active manganese as 15 ppm for the level of deficiency, 15 to 100 ppm as critical level and above 100 ppm as high in available manganese.

Continuous use of ammonium sulphate for a long time increased the availability of manganese in soil (Bingham et al. 1958, Bandypadhy & Adhikari 1968 and Bear 1968). The ingredients of phosphatic fertilizer lowering the soil pH would have much solubilising effect on Mn (Frank & Garber 1960). Larsen (1956) reported that heavy doses of superphosphate increase the availability of Mn and the effect was mainly attributed to direct influence of phosphate on the solubility of Mn in soil. On the other hand, Badamur & Venkata Rao (1973) observed that heavy applications of phosphatic fertilizers in the soil type of red sandy loam reduced the available Mn. Superphosphate had a negative effect on the content of exchangeable and easily reducible Mn. A positive effect of potassium chloride on
exchangeable Mn was clearly observed. According to Cheng & Doiron (1974) heavy doses of ammonium nitrate along with potassium chloride markedly enhanced the exchangeable Mn status in soil. Avdonin et al. (1960) reported that N and NP treatments could raise the available Mn by almost 3 times whereas its content was relatively lower with NPK treatment. However, Mandal and Sinha (1964) found that NPK could considerably raise the manganese levels in soil resulting in much higher concentrations in the crop growth.

Follett & Lindsay (1971) found that in most soil, DTPA-extractable Mn declined due to cropping and fertilization. McIntosh & Verney (1973) and Warnock (1970) observed that its content was increased slightly by the addition of highest dose of nitrogen and decreased by addition of highest rate of manure. Warnock (1970) obtained an increase in DTPA-extractable Mn at higher level of applied P. Vogter (1949) in a long-term experiment observed an increase in available Mn as influenced by continuous use of dung. Which enhanced carbon and nitrogen content in soil also tended to raise the total and active manganese (Brage et al., 1952; and Maurya & Ghosh 1972).

2.6.3. Iron

Indian soils contain available iron ranging from traces to 960 ppm (Kumar and Randhawa 1987). Ferrous iron is the most readily acceptable form of iron taken by the plants. Its availability is governed by a number of factors which influence
Mineral potential, hydration and dehydration of iron compounds.

Normally, ferric iron content increases with a fall of soil pH (Singh 1964 and Bhumbla et al. 1965). Iron is converted to an insoluble ferric state under alkaline conditions and its deficiency may be accentuated (Singh 1964 and Berger 1965). Lindsay & Norvell (1969) determined available iron using DTPA as an extractant and indicated a critical range from 2.5 to 4.5 ppm Fe.

Excessive use of phosphatic fertilizers reduces the availability of iron (Frank & Garber 1960 and Garnock 1970) but no consistent evidence could be found. A positive effect on the content of exchangeable iron due to application of ammonium nitrate and potassium chloride was obtained by Cheng & Doiron (1974). Follett & Lindsay (1971) obtained a conspicuous increase in DTPA-extractable iron in all soils. This could be due to the activity of microorganisms and plant roots producing chelating agents which tended to hold more iron in solution.

Miller and Hodge (1968) pointed out that chelation of iron by soil organic matter and its decomposition products made the iron in soil less available. Ayer (1968) reported an inverse relationship between K and Fe regarding the influence of other nutrients. It was the observation of Berger (1965) that iron deficiency in acid sandy soils might be due to accumulation of copper.
2.6.4. Copper

Swaine (1955) quoted several results on the content of total copper ranging from 1 to less than 100 ppm in the normal agricultural soils of the world. According to Neelkantan & Mehta (1961) most of the crops have required available copper ranging from 0.1 to 2.0 ppm and a constant supply of about 0.5 ppm has appeared to be quite adequate.

Neelkantan & Mehta (1961) and Agarwal & Motiramani (1966) have generally accepted a decrease in the available copper with the increase in pH. A significant positive correlation with the soil organic matter was obtained as a result of the amount of exchangeable copper in soil (Rai & Mishra 1967, and Grewal et al. 1969). Bingham et al. (1968) reported a decrease in the content of available Cu due to a heavy application of monocalcium phosphate to a sandy loam soil. Frank & Garber (1960) and Badanur & Venkata Rao (1973) marked a severe reduction in available Cu content in soil due to repeated and heavy application of phosphorus fertilizer. The microbial activity in soil was promoted by phosphorus; as a result available N was increased.

Phosphorus enhanced the activity of soil microorganisms which resulted in an increase in available nitrogen, thus upsetting the nutritional balance and ultimately causing a deficiency of Cu in soil. Application of N & P to rice soils on long-term basis showed no reduction in available Cu (Sandyopadhyya and Adhikari 1966). Cheng & Doirou (1974) reported that ammonium
nitrate and potassium chloride had a positive effect in improving the exchangeable Cu content in soils. Cropping and fertili-
ization brought no change in DTPA-extractable Cu, observed by
(Follett and Lindsay (1971).

2.7. Effect of Herbicidal Chemicals on the Crop
Yields, Nutrient Composition and Uptake by
Plant and Soil Fertility Status

On these aspects information available in literature is
quite meagre. During recent years some are interested to find
out the effect of regular use of biocidal chemicals in soil on
the crop yield and soil productivity.

2.7.1. Crop Yield

It is a matter of fact that a good number of manpower and
time involving a huge amount of expenditure are needed in hand
weeding operation as compared to chemical method of weed control
(Verma 1970). Some workers (Smith 1961; and Manna et al. 1971)
reported a good control of weeds and in many cases increase in
yield by post-emergence application of herbicides in direct seeded
rice plants. Application of atrazine to maize and prometrine to
potato increased the yields as reported by Khomenko (1969). The
use of MCPB and (stam F-34) on both direct seeded and transplanted
rice controlled the weeds and yields obtained were nearly identi-
obtained in his recent observation a higher yield due to hand
weeding in direct-seeded upland rice than chemical weeding.
2.7.2. Nutrient Composition

Gill and Burley (1970) came out with an observation that the use of 2, 4-D decreased N & Mn concentration in leaf sheaths significantly while 2, 4-DB increased the concentration of N, P, K, Ca & Mg and no change of Fe, Cu, Zn was obtained. Pre-emergence application of atrazine, simazine, Trepian or Ramrod in a three-years test conducted by Bzikov et al. (1971) increased the concentration of P, K, Na Ca & Mg in maize the effect being more distinctive in the vegetative parts than in the reproductive mass. Shimanski (1970) reported that soil application of simazine increased the percentage concentration of N, P & K in the plants. Soundarajan (1974) reported that hand weeding in rice at all growth stages registered a significant concentration of nitrogen. According to Rudgers et al. (1970) atrazine slightly increased P & Zn in leaf blades of maize and this herbicide would be unlikely to aggravate which induced zinc deficiency in crops.

2.7.3. Nutrient Uptake

From the investigation conducted by Abuova & Bagaev (1974) it has been found that spraying with MCPB could enhance markedly the uptake of N, P & K by the test crops, similar was the case of 2,4-D which promoted the crop uptake of the nutrients from the source of applied fertilizers. Further Soundarajan (1974) showed that repeated hand weeding increased the N uptake by the crops as compared to the use of weedicides, and further he indicated a favourable influence on the uptake of P, K & S by the rice crop.
2.7.4. Fertility Status of the Soil

Bliev (1973) reported from a two-year experiment that the herbicides dalapon and gamine salt of 2,4-D did not have much effect on the humus and total N contents of the soil. These somewhat increased the mobile P content but there was no influence on exchangeable K. According to Kelperis & Pippas (1968), annual use of simazine or atrazine for the period of four years produced a higher soil organic matter content in the status-over-control. Shankar & Kumar (1969) observed that the availability of N & P was not markedly affected by herbicide treatments but there was a slight decrease of K availability. Use of herbicides in a sandy loam soil (pH 7.0) which was kept bare or cropped with barley, maize or carrot produced no major change in the levels of available N, P and that of pH content (Fryer & Kirkland 1970). Fisyunov (1972) came out with a conclusion from a three-year experiment that triazines applied in heavy loam soil did not affect the mobile P content up to plough layer. Medvedev & Burmistrov (1973) found that a mixture of picloram/TGA, picloram/dalapon and 2,4-D/dalapon clearly favoured the accumulation of available N & K in the soil. Beikov et al. (1971) observed an increase of N, P & K accumulation in the soil of three-year experiment due to pre-emergence application of herbicides.