Studies On The Effect Of Liming On The Forms Of Phosphorus And Soil Properties in An Alfisol Of Palampur

THESIS

by

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DEDICATED

TO

MY BABA

CERTIFICATE - I

This is to certify that the thesis entitled, "Studies on the effect of liming on the forms of phosphorus and soil properties in an alfisol of Palampur" submitted for the degree of MASTER OF SCIENCE (AGRICULTURE) in the subject of Soil Sciences and Water Management of Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, is the bonafied research work carried out by Shri Ravinder K. Bhardwaj son of Shri Jager Nath Bhardwaj under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and the help received during the course of investigation have been fully acknowledged.

R.Sood

Palampur
Dated : 30.1.86

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Major Advisor

CERTIFICATE-II

This is to certify that the thesis entitled, "Studies on the effect of liming on the forms of phosphorus and soil properties in an alfisol of Palampur", submitted by Shri Ravinder K. Bhardwaj, son of Shri Jager Nath Bhardwaj, to the Himachal Pradesh Krishi Vishva Vidyalaya Palampur, in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in the subject of Soil Sciences and Water Management has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with an External Examiner.

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All errors are mine,

29. 1. 86

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INTRODUCTION

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INTRODUCTION

Soil acidity is common in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface layers. The adverse effect of acid soils on plant growth is mainly related to the presence of aluminum, manganese and iron in toxic concentrati low availability of bases, microbial and nutrient imbalances. The nutrition deficiency in acid soil is more severe in relation to availability of phosph and molybdenum. Phosphorus presents a special problem in that it is subject to rapid fixation principally by iron and aluminum compounds either by precipitation or by surface chemi-sorption reactions.

Acid soils pose a serious problem to Indian agriculture as out of 175 million hectare of total gross cultivated area 1/3 of it is under acidic soils. The major processes involved in formation of acid soils are laterisation of varying degrees, podzolisation in areas with sub-temperate to temperate climate, intense leaching of light alluvial soils and marshy conditions with significant amount of partly decomposed organic matter (Mandal *et al.*, 1975). The strongly acid soils are found in the States of Orrisa, Bihar, Kerela, Karnataka, West Bengal and Himachal Pradesh particula in Kangra district. Acidity problem can be solved by a joint effort of breeding and soil management. For several years a major effort has been made by plant breeders to obtain plants able to grow satisfactory under acidic conditions, however, they could not exclude the process of liming.

The use of agricultural lime has been recognised down through the ages as a practice that is basic to good husbandry in humid regions. In acid soils lime is generally credited with the ability to make more of the native P and added P available to crops. This is particularly true for the soils high in iron and aluminum. Since these metallic cations and their oxides control the fixation and availability of applied and native soil phosphorus, the practice of liming has direct bearing on the P availability. In order to improve the P-availability in acid soils use of lime has long been propagated (Hartwell and Pember, 1918). Pearson (1958) reported that lime usually depressed the immediate availability of soluble phosphate fertilisers while it usually improves its long term residual availability by slowing down its relatively permanent attachment to the iron and aluminum oxides. One can, thus, visualise the effect of liming on the availability of residual phosphorus as well. These observations.suggest that logical approach to make acid soils more favourable for plant growth with reference to P might involve the combined application of lime and phosphate in optimum proportions.

Phosphorus in agricultural soils has been investigated as much as or more than any other plant nutrient presumably because it is a major nutrient element and also in view of the complex reactions that it undergoes with soil constituents. The nature and forms of soil phosphorus has provided useful information for assessing the soil available phosphorus status. The problem of P-fertility in acid soil has attracted much attention regarding P-fractions in the recent years. The active forms which include Ca-P, Al-P and Fe-P are the forms that are available to the plants with the degree of availability in different orders in different soils.

Acidity in Himachal Pradesh soils has been recognised to the extent of 25-30 per cent. The soil acidity problem in Himachal Pradesh is of paramount importance, as acid soils occupy a sizeable acreage (0.102 m ha) of cultivated area. These soils are found in Chamba, Kangra, Kullu, Mandi, Shimla and Sirmour districts of the State (Bishnoi, 1979). It is [redacted] because of this high acidity,yield per hectare of wheat crop is 12.1 q/ha against 29.0 q/ha of India (recommended by National Commission on Agriculture). High rainfall in Kangra district aggravates this situation all the more by creating many problems of availability and fixation of plant nutrients particularly the added soluble phosphorus. Keeping in view the low status of phosphorus in the acid soils of Palam Valley of wet-temperate region, the present investigation was undertaken with an aim to get more information about the effect of liming on different fractions of phosphorus and with the following objectives:

1. To study the status and forms of phosphorus as affected by liming and P-application.
2. To correlate the yield of wheat crop with different P-fractions under different levels of lime and P-fertiliser.
3. To study the changes in soil properties as pH, organic carbon, available N, P and K and basic cations on the application of different levels of liming and P-fertiliser.

CHAPTER-II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

Soils with preponderance of H^+ and Al^{+++} ions in proportion to hydroxyl ions having pH below 6.5 are viewed as acidic soils and need special remedial measure. Nearly 49 million hectare of soils have acidic reaction and predominantly occur in the regions of high rainfall comprising about 30 per cent of the total and 20 per cent of the cultivated area of the country. The theoretical implications associated with acid soils problems are among the most fascinating one. The review of literature pertaining to the present investigation is presented under the following heads:

I. Status and forms of P
    i) Abundance (a) inorganic-P
        (b) organic-P
    ii) Effect of lime on P-fractions
        (a) inorganic-P fractions
        (b) organic-P fraction
    iii) Effect of added P on the changes in P fractions.

II. P fractions in relation to wheat yield as influenced by lime and P application.

III. Effect of lime and P on soil properties.

I. Status and forms of P

i) Abundance (a) Inorganic P

The relative amount of inorganic-P fraction differs in different soils. In acid soils, Al-P and Fe-P are the dominant fractions whereas Ca-P is abundant in alkaline calcareous soils (Chai and Caldwell, 1959; Chiang, 1963, 1968; Morrillo and Fassbender, 1968).

Karim and Khan (1955) expressed the opinion that the sesquioxides bond-P (Al-P and Fe-P) increased as the pH increased upto 5.6 but decreased on the other hand, as the pH increased from 5.6 to 6.2. Scheffer et al. (1960) while working on some soils of West Germany, reported that acid soils (pH 5.8 to 6.3) having low $CaCO_3$ content (0-0.65%) exhibited the dominance of Fe-P and Al-P (24-49%) with the subordinate position of Ca-P (13%). Ulrich and Khanna (1968) from West Germany reported that between 4.5 and 6.8 Al-P and Fe-P were present in abundance. Likewise, Fe-P was the most dominant P-fraction in some acid soils of Uttar Pradesh (Bhan and Shankar, 1973), and also in the typical acid soils of South India (Vijaychandran and Raj, 1973).

Khan and Mandal (1973) conducted studies on few acid low land rice soils of West Bengal, ranging in pH from 4.9 to 6.6 and found that Al-P and Fe-P fractions constituted about 7.2 and 27.8 per cent of the total inorganically bound P. Enwezor and Moore (1966) reported that the acidic soils of Savanna and forest zone of Nigeria had Fe-P as the dominant form, while in some cultivated soils of the same country, occluded-P was the dominant inorganic-P fractions followed by Fe-P, Al-P and Ca-P (Uzu et al., 1975). McKenzie et al. (1977) and Rhodes (1977) demonstrated that Al-P and Fe-P fractions were present to the extent of 6 to 12 per cent of the total P in tropical acid soils of Sierra Leone in West Africa and that the Ca-P was virtually absent in these soils.

Studies conducted by Kadeba and Boyle (1978) showed that inorganic-P was mainly present as Al-P and Fe-P in acidic soils (pH 4.8 to 7.0) of forest zone of Wisconsin (U.S.A.). Sharma (1979) while investigating the inorganic-P fractions in some acid soils of Himachal Pradesh, concluded that the average relative abundance of these fractions in terms of their ratio was 0.12 : 1.0 : 2.65 : 1.0 as Saloid-P, Al-P, Fe-P and Ca-P, respectively.

b) Organic-P

The information regarding the availability of organic-P to plants is relatively limited although it is known that plants can absorb directly the soil organic-P for their nutrition (Pierre and Parker, 1927). However, its use in plant nutrition, organic-P has to be mineralised into inorganic-P (Eid et al., 1951).

The organic-P content of soils varies between 20 and 80 per cent of the total P in the surface layer of cultivated soils although extreme values of 4 per cent in alpine humus have been observed (Williams and Steinbergs, 1958). Kaila (1956) stated that some virgin peat lands may contain as high as 95 per cent of total-P in organic form especially at lower depths.

In India, the work of Goel and Agarwal (1959) revealed that organic-P constituted about 10-20 per cent of total P in Indo-Gangetic alluvium derived soils of Kanpur whereas it constituted about 2 per cent of total-P in some soils of Gujarat (Patel and Mehta, 1962). Some soils of Punjab and Haryana were found to have organic-P to the extent of 8-233 per cent of total P (Singh and Arora, 1969). Joshi and Saxena (1979) reported that maximum amount of organic-P was found in non-humus fraction followed by Beta-humus, fulvic-humus, humic acid whereas humin did not contain organic-P in the soils of Rajasthan.

Sharma, Bhumbla and Dev (1982) reported that the grey brown podzolic soils of Himachal Pradesh varies in organic phosphorus as per cent of total phosphorus with minimum value of 27.9 (Bhawarna) to 77.6 (Chachian) in the surface layer, whereas at Palampur it was 68.9 per cent in 0-20 cm depth.

Sood (1983) reported that organic-P content in soil profiles ranged from 11 to 423 ppm, with a mean value of 110.4 ppm for the State

(Himachal Pradesh) and its highest content was found in subhumid temperate highland and lowest in subhumid subtropical zone of Himachal Pradesh.

ii) Effect of lime on P-fractions

a) Inorganic-P fraction

Mandal (1964) while studying the transformation of inorganic-P in waterlogged rice soils of West Bengal, found that in the presence of lime the ferric and aluminium phosphates decrease, the former considerably and later slightly. He further observed that calcium bound phosphate increased appreciably and some of ferric phosphate got converted to Ca-phosphates. Thus, in acid soils with most of the inorganic-P as ferric phosphate, the use of lime followed by organic matter may increase its availability under waterlogged conditions.

A laboratory study was undertaken by Mahapatra (1969) to determine the distribution of inorganic forms of native and added-P as a result of liming under air dry and waterlogged conditions. Liming reduced all the fraction of native and added inorganic-P except Ca-P fractions. Consequently the extraction-P was also reduced in air dry and waterlogged soils. Cotton and Corn were the test crops and lime @ 3.36 t/ha was applied to the soil (pH 5.6 to 6.5).

Haynes and Ludecke (1981) demonstrated in their pot experiment the effect of lime and phosphorus fertiliser using two pasture legumes lotus and white clover on the inorganic-P fractions that lime addition caused a decrease in the easily soluble, Fe-P and to a lesser extent to Ca-P, no effect on the reductant soluble-P but resulted in the increase in Al-P fraction.

Effect of liming three acid soils on the distribution of native and added P in different inorganic phosphate fractions and their lability was studied by Dev Nath and Mandal (1983). Liming, however, did not bring any significant change in the relative abundance of the native inorganic-P fractions, but it decreased surface P and specific surface activity of native Al-P and Fe-P, effect on Ca-P was non-consistent. While the retention of applied P in saloid bound form was favoured, its transformation to Al-P, Fe-P and reductant soluble forms was suppressed in limed soils; transformation to Ca-P remained unaffected in the two soils of alluvial origin and was slightly increased in the laterite one. Liming increased the surface P and specific surface activity of Al-P and Fe-P formed in the former two soils and decreased in the latter.

b) Organic-P fraction

Sood (1983) reported that liming of acid soils to a pH of 7.0 showed that the mineralisation of organic-P was maximum in soils having more organic matter content. The rate of mineralisation was maximum after first 10 days and minimum at 40 to 60 days of incubation. Kaila (1948) and Stevenson (1964) found that limed soils contained less organic-P than the soils of corresponding acid, and unlimed plots. These results can be explained on the basis of organic-P mineralisation.

Ghani and Aleem (1943) showed a decrease in organic-P upon liming acid soils indicating that the rate of organic-P was increased markedly with pH increase in 20 unlimed soils (Thompson et al., 1954). The rate of mineralisation was found to be enhanced by adjusting the pH at optimum level (or microbial metabolism, through liming of acid soils (Islam and Ahmed, 1973; Pearson et al., 1941). Islam and Mandal (1977) reported that liming the soil to raise pH from 5.2 to 8.0, increased the mineralisation progressively and the highest value was reported for the soil with 8.0 pH. Later Mandal et al. (1982) also found that maximum mineralisation took place in first 30 days when soil was incubated with lime. The mineralisation was more in soils containing more organic matter and it increased with pH, as it induced conditions for proliferation of phosphate transforming organisms

iii) Effect of added P on the changes in P fractions

The transformation study of applied P into particular inorganic-P forms is of great importance because plants obtained most of the phosphorus from the reaction product and not from the applied source as such. Such type of transformation are greatly affected by moisture content, time of reaction in the soil and other physico-chemical properties of soils (Sharma et al., 1980). Yuan et al. (1960) reported that over 80 per cent of the added P was retained by the soils as Al-P and Fe-P while less than 10 per cent in saloid-P and Ca-P by the three acid sandy soils. They further reported that the ratio of Al-P to Fe-P increased with the levels of applied P in these soils. Kanwar and Grewal (1960) while working on some acidic soils of Kangra district of erstwhile Punjab, reported that 72.2 per cent P retention was due to free sesquioxides. In the four acid soils of Ohio (U.S.A.), Volk and McLean (1963) studied the fate of applied P in relation to magnitude of P-fixing capacity and concluded that almost all of the applied P was recovered in Al and Fe phosphates. In five West Bengal acid soils (pH varying from 4.3 to 6.2) previously treated with KH_2PO_4 solution, about 30-50 per cent of the added soluble P was found to get fixed revealing appreciable change in Al-P, Fe-P and reductant soluble Fe-P (Kar and Chakravarti, 1969).

Mandal and Das (1970) studied the transformation of applied water soluble phosphate in three acidic low land rice soils of West Bengal (pH 5.3 to 6.0) in relation to these physico-chemical characteristics and found that saloid-P fraction in P-treated soils showed practically no increase over the untreated ones in all the three soils. The magnitude of increase appeared to be influenced by total and active Fe-content rather than by the pH of the soil. Ca-P fraction showed little increase in all the soils on application of phosphate. It was further observed that the transformation of applied P in acidic soils of erstwhile Punjab was different than in alkali and calcareous soils. More than half of the conversion of added-P in acid soils was in the form of Al-P (47 to 73 per cent at pH 4.7) and (35 to 56 per cent at pH 6.6) followed by Fe-P (18 to 44% at pH 4.7) and (17 to 34% at pH 6.6).

Devnath and Hajra (1972) investigated the transformation of added P in some acid soils (red hilly and laterite) of Bhubaneshwar (pH 5.3) in West Bengal in relation to soil characteristics vis-a-vis moisture regime and reported that most of the added-P was recovered in different inorganic P forms in the order, Al-P Fe-P Ca-P.

While conducting studies on some soils of Palampur (Himachal Pradesh) under waterlogged and upland conditions, Singh and Bahanan (1976) reported that waterlogging increased available P after 20 days of incubation and also significantly increased Fe-P, Al-P while Ca-P decreased with the period of incubation. Saloid-P did not change. A similar trend in available P and other P-fractions was observed under upland soil conditions.

Mandal and Khan (1977) while working on three acid soils ranging in pH from 4.9 to 7.5 of West Bengal suggested that 60 to 75 per cent of the amount of applied-P was found in the field form as Al-P, Fe-P and Ca-P.

Recent investigation carried out by Sharma et al. (1980) on three acid soils of Himachal Pradesh for an incubation period of 1, 7, 30 and 90 days revealed that most of added P was transformed into Al-P, Fe-P and very little to Ca-P fraction at one day interval. The added P which was transformed into Al-P increased upto 7 days and later decreased slowly with time upto 90 days. The conversion of added P into Fe-P fraction increased slowly with time upto 90 days. Very little P was changed into Ca-P even at prolonged time-intervals. Transformation of added P into Al-P and Fe-P fractions was found to be related to pH , clay , organic matter, sesquioxides and P-fixing capacity of the soils.

II P-fractions in relation to wheat yield as influenced by lime and P application

Inorganic-P fractions play an important role in plant nutrition and keeping this in view, Sharma et al. (1980) emphasized that Fe-P was the most important inorganic-P fraction contributing P to wheat crop in some light textured acid soils of Himachal Pradesh.

Recently, Verma and Tripathi (1980) revealed that Fe-P was the most important inorganic-P fraction in contributing P to rice crop followed by Al-P fraction in some acid soils of Himachal Pradesh. Chaudhary et al. (1974) emphasized the importance of Fe-P as a source of P to Jower and Urd crops, whereas Ca-P provided significant correlation with P-uptake by cowpeas in some soils of Rajasthan (soil pH 6.8-8.3).

Singh et al. (1966) reported that plants growing on Davidson soils (pH 6.8) in Virginia (U.S.A.) previously treated with concentrated superphosphate utilised Al-P, Fe-P and Ca-P during the first year of growth and Fe-P only during the second year of growth.

Enwezor (1977) found that percentage yield of maize correlated positively with each of Al-P, Fe-P and Ca-P fraction in some south-eastern Nigerian acid soils, suggesting thereby that all the three forms of P contributed to the available P for maize crop. In some Tamilnadu soils of South India, Fe-P, Saloid-P and Al-P were reported to be the important inorganic-P fractions contributing to the plant available P in rice crop (Perumal and Velayutham, 1977).

Lawton and Davis (1956) studied the effect of liming on two strongly acid Rifle peat soils on the growth and absorption of soil and fertiliser P by field beans, sudan grass and corn under green house conditions. The dry weight of field beans was markedly increased by applying 12 tonnes of $CaCO_3$ per acre. In contrast the growth of the corn was depressed when more than 3 tonnes of $CaCO_3$ per acre was applied. Liming has little or no effect on the yield of sudan grass.

Haynes and Ludecke (1981) while working on the effect of increasing rates of liming and P addition on concentrations of available nutrients in soil and on P, Al and Mn uptake by two pasture legumes, lotus (Lotus pedunculatus Cav.) and white clover (Trifolium repens L.) were studied in a pot experiment using highly leached soil (pH 4.2), reported the correlation between available phosphates indices and yield of both legumes were weak or non-significant. However, high, significant positive correlation co-efficient were found between available P and plant uptake of P.

Optimum growth of fescus was obtained 40 kg per hectare of fertiliser P, when enough lime was added to neutralise exchangeable Al as compared to 160 kg per hectare of P on unlimed soil (Shoop et al., 1961). Marked lime x P interactions have been obtained on white clover, red clover and subterranean clover on the red soil experiment station in Western Oregeon (Jackson et al., 1964). Hoyt et al. (1967) observed that in a green house experiment lime applied to soils from the Peace River region caused decrease in barley yields no P was added and increased the yield, when P was added.

Lutz and Jones (1975) while conducting an experiment on lime and P-fertilisers effects on yield and chemical composition of soybean reported the increase in yield and protein content. Badnur et al. (1976) reported that in trials with black gram on red sandy loam soil (pH 5.0) of Bangalore, application of one ton of lime plus 96 kg P_2O_5 per hectare gave seed yields of 1.54 t/ha as compared with 0.61 t/ha without lime and phosphorus.

At Ranchi, pronounced effect of liming on wheat yield was reported when applied alone or in combination with phosphate. An apparent residual effect in subsequent years was also noted by the workers (Mandal and Jha, 1970). Ekpte (1972) conducted pot experiment with soybean on twenty Eastern Nigeria soils of different genetic and morphological locations. He reported that liming to pH values, between 6.5 to 7.0 increased the mean dry matter yields and the uptake of N, P and K but higher levels of lime decreased the yield and uptake of nutrients, as well.

Mukhopadhya et al. (1967) and Giordano and Morvedt (1972) noticed that dry matter production and P-uptake was doubled and zinc uptake was upto five times greater when the rice plants were grown on limed soil under flooded rather than moist soil. Porticles and Mojena (1979) conducted a field experiment in which single superphosphate @ 100-300 kg/P_2O_5 increased the dry matter yield of Pangola grass pasture. [redacted] The application of ground lime (0.65 to 3.00 tonnes $CaCO_3$/ha) did not affect the yield of the test crop.

III Effect of lime and P on soil properties

Alban and Lin (1958), Moscheler *et al.* (1960) reported that liming increased pH, exchangeable bases, base saturation and CEC of acid soil. Wiklander (1960) while working on influence of liming reported that two important reactions take place between soil and lime.

i. $R\ H_2 + CaCO_3 = R\ Ca + H_2O + CO_2$

ii. $R\ Al_2 + 3\ CaCO_3 + 3\ H_2O = R\ Ca_3 + 2\ Al(OH)_3 + 3\ CO_2$

Where R, H and Al stand for soil complex, exchangeable hydrogen and exchangeable aluminum, respectively.

Lime and P-application in acid soils invariably improved soil productivity through various changes in physico-chemical properties of soils and availability of plant nutrients, as described under the following heads:

1. Effect on soil pH

Perhaps the most important chemical test of a soil as a medium for plant growth is its pH value (Jackson, 1958). The availability and solubility of many nutrients are closely related to soil pH (Truog, 1948). Alban and Lin (1958) reported that liming of acid soils initially increases soil pH and raises the concentration of Ca^{++} and OH^- ions of the soil solution. Savant and Kibbe (1972) studied the influence of added $Ca(OH)_2$ on pH and soil acidity. These workers concluded that by adding $Ca(OH)_2$ equivalent to 92 per cent of total acidity helped in raising the pH to neutrality.

Barde (1956) noted that pH was raised to 7.1 as a result of addition of lime equal to lime requirement in acid soils of Chiphlum. Varade (1963) reported that application of lime in increasing doses to

Sindewalri soil did not produce any appreciable change in soil pH. Zonde *et al.* (1968) found that by the application of $CaCO_3$, the pH of the soil was raised, however, the increase was not achieved upto the desired level even after 28 months. Badanur and Venkata Rao (1975) showed a slight increase in pH as a result of addition of P in the form of superphosphate with lime application. Yaduvanshi (1980) showed that application of lime combined with fertiliser resulted in an increase in pH but it was not to the extent compared with liming alone. Mandal *et al.* (1955) conducted experiments on acidic sandy loam soils of Islampur farm in early fifties for change in pH and degree of calcium saturation by liming at moderate and heavy doses reported progressive rise in pH from 5.3 to 6.2 with moderate liming and from 5.2 to 7.05 under heavy liming. Again Mandal *et al.* (1975) reported a rise in soil pH from 5.5 to 6.3, 6.5, 6.8 and 7.3 and increase in per cent of Ca^{++} by 14.7 , 32.4, 64.7 and 79.4 with respective doses of Ca^{++} application.

Sinha et al. (1965) conducted another experiment on acid loam soil of Chota Nagpur during 1956, 1958 and 1961 by applying 2700 kg/ha lime with and without NPK. Their data showed considerable rise in soil pH in first year but such increase in pH was not found in subsequent years due to the fertiliser application.

2. Effect on organic carbon

Prasad et al. (1976) observed that liming increased the rate of oxidation of organic matter, brought about increase in pH, exchangeable Ca^{++}, P and lime potential value of the soil. Mandal *et al.* (1969) and Sharde (1978) reported that the addition of lime accelerated the rate of decomposition of organic matter. Beneficial effect of phosphatic fertilisers in increasing the organic carbon content of the soil has been reported by Kanwar and Prihar (1962) and Pharande and Biswas (1968). Vig and Bhumbla (1970) and Sandhu (1971) found that application of FYM and P-fertilisers increased the organic carbon of the soil. Prasad et al. (1971) reported that the application of lime alongwith fertiliser (L+NPK) reduced the value of organic matter. Organic matter content of the Hebbal Red loamy soils increased to the extent of 2.14 to 22.8 per cent over control with the addition of lime and phosphorus in combination indicating the increase in available N of soil (Badanur and Venkata Rao, 1975).

3. Effect of availability of plant nutrients

The role of lime in the correction of the undesirable effects of soil acidity on plant growth is probably the most complex role to be found in soils (Pearson, 1958). Liming alongwith phosphorus increase the solubility of other nutrient ions rapidly (Alban and Lin, 1958; Wiklander, 1960). The relationship between the plant nutrient availability and soil pH is an important one and liming is well known for its soils ameliorating effect due to the decreased mobility of toxic Al, Fe and Mn (Motiramani, 1971). The availability of micro and macro-nutrients, particularly of anion micronutrients is increased by liming acid soils (Jackson, 1967).

Nitrogen

Application of lime has been reported to increase the availability of soil N by number of workers (Abhichandani and Patnaik, 1961; Balasco and Cornfield, 1967; McLean, 1970; Munus et al., 1977). It is either due to increase number of amonifers (Kolzov, 1955) or nitrifiers (Jha, 1965), which ultimately increased the N-content of the soil through accelerating the rates of ammonification, atmospheric N-fixation and nitrification processes. Sahu (1965) also noted higher content of nitrogen in limed plots.

Application of 560 kg/ha of lime increased available N from 297 to

323 kg/ha in Madhya Pradesh soils (Motiramani, 1967). Further, gradual increases in the amount of lime applied upto 3360 kg/ha did not increase the availability of nitrogen. Increased nitrate production occurred as the pH was raised from 5.0 to 6.2 and then to 7.4 (Pearson, 1958), with the reasons that applied NH_4-N was converted to the more readily leached nitrates form in limed soils faster than in very acid-unlimed soils (Wakesman, 1952).

The losses of N from acid sandy soil as both nitric oxide and N_2 amounted to as much as 74 per cent of the added NH_4-N ceased when sufficient $CaCO_3$ was added to raise the pH about 5.5 (Pearson, 1958). Nyberg and Hoyt (1978) reported that liming the soils to about pH 6.7 approximately doubled the amounts of available N during incubation. They further reported that nitrification was significantly related to the base saturation.

Borthakur and Majmudar (1968) reported that liming increased average mineral N content of acid soils significantly under low moisture conditions. Perus et al. (1973) concluded that the presence of lime accelerated the rate of nitrification significantly. Leaching losses of ammonium can also be decreased and the residual value of subsequent crops of the unused portion of applied N fertiliser improved by the proper use of lime (Volk and Bell, 1944). Liming is, thus, seen to give increased crop growth with a consequent improvement in the utilisation of both applied and native nitrogen.

Organic matter content of Hebbal Red loamy soils increased to the extent of 2.14 to 22.8 per cent over control, with addition of lime and P in combination indicating the increase in available N of soil (Badanur and Venkata Rao, 1975).

In a long term experiment being conducted oh acid alfisol at Palampur since 1972-73 it was noted that available N increased on an average upto 822.8 and 835 kg/ha in NP and NPK+lime treatments, respectively, during 1972-73 to 1979-80 over initial values of 736 kg/ha (Anonymous, 1980).

Phosphorus

Phosphorus has been one of the first limiting factors for crop production in many of the virgin soils throughout the world (Peech, 1946 and Wilson, 1956).

The extensive investigations were summarised by Wheeler (1897) while dealing with the liming of acid upland soils and attracted attention to the favourable influence of this practice on P-availability. Hilgard (1907) believing "A lime country is rich country" stressed the favourable influence of lime on the availability of soil P. Albracht and Klemme (1939) reported that application of limestone and superphosphate to mineral soils approximately doubled the P-content of Lespedza forage over the contained in plants from soil receiving superphosphate alone.

Neller (1953) was of the opinion that in acid soils lime is generally credited with the ability to make more of the P of and added phosphate available to crops particularly true for soils high in Fe and Al. Liming of laterite soil from Ratanagiri district increased the efficiency of added soluble P_2O_5 (Gokhle et al., 1954). Mariakulandai et al. (1955) reported that P added to laterite soils of Nilgiris was fixed by the free Fe and Al oxides present in high amounts in these soils. When lime was applied to these soils it resulted in greater availability of P by reducing its fixation. Kanwar and Grewal (1960) observed that phosphate fixation decreased with the increase in pH and degree of base saturation.

Stewart and Pearson (1952) found that liming increased the availability of soil-P and decreased the percentage uptake by crimson clover from fertiliser. Salter and Barnes (1935) reported that maximum availability of both native and added-P in Ohio soils was attained at approximately pH 7.0 and lime alone produced nearly as large yield of some crops as did lime plus phosphate. Taylor and Gurney (1965) carried out a study on five acid soils. Four out of five acid soils showed a decrease in P-concentration with the addition of first level of $CaCO_3$, with the further addition there was no definite trend in the P-concentration of the solution. However, they found that the resin-extractable P-increased with liming on all the five soils.

Beneficial effects of lime on the availability of native and added P from acid soils are well known (Singh and Seatz, 1961). Evidence of greater availability of P as rendered by liming of acid soils has been furnished by Rai et al. (1963). Mathan (1964) observed that acid soils of Nilgiris responded to lime by releasing more P_2O_5. Motiramani (1967) reported increase availability of P (17 to 22 kg P_2O_5/ha) on application of 3360 kg $CaCO_3$/ha in Madhya Pradesh soils.

In the acidic alluvial soils of Assam, the beneficial effect of lime on P-availability has been reported by Roy (1967). Thus increased availability of soil-P is often cited as one of the principal benefits desired from liming acid soils (Griffin, 1971, Amrasiri and Olsen, 1973). Sahi et al. (1969) suggested that liming increases availability of P only upto four to five months and thereafter the availability decreases due to reversion of soluble P to difficult soluble forms. Rai et al. (1963) reported that the available P-content of the acid soil from Kanke farm in Bihar did not increase due to liming. On the other hand, there was a definite increase of P-concentration in plant leaves in limed plots indicating higher uptake of P by plants due to liming.

Iyengar (1963) working on physico-chemical characteristics and nutrient status of Malnad soils of Mysore state found an increase in the availability of P when applied alongwith lime. Rai et al. (1963) reported that P-fertilisers and lime increased the available P content of the soil. The application of superphosphate alongwith lime increased the level of available P_2O_5 in Amgon soil (Bhujbal, 1956).

Badanur and Venkata Rao (1975) working with Hebbal red soils studied cumulative effect of application and additive influence of P and lime application. Liming alone at the rate of 2 tonnes per hectare increased the available P content of the soil by 4.9 ppm over initial valuo of 4.3 ppm. On the other hand, when P at the rate of 40, 80, 160, 320 kg P_2O_5/ha applied with the lime doses, the increase in the available P were found to be 9.2, 11.' 18.9, 20.7 ppm respectively, over control. In recent review for example, Sauchez and Vehara (1980) stated that liming variable charge acid soils to a pH of 5.5 to 6.0, decreases but not eliminate P-fixation.

Potassium

The application of lime has been reported to increase, decrease or cause no effect on the K-availability in soils depending upon initial degree of base saturation (Peech and Bradfield, 1943; Thomas and Hipp, 1968; Gupta et al., 1977). However, liming a very acid soil was found to increase K availability (Varghese and Money, 1965; Motiramani, 1967; McLean, 1970). This may be due to the fact that liming reduced the leaching of K in certain strongly acidic soils which increase levels of exchangeable K in the surface soils (Krause, 1965; Black, 1968; Mehilum et al., 1970).

York and Rogers (1947) while measuring the influence of lime on either K-release or fixation, operating at some time, pointed out that these effects found dependent upon the K content of the soil, its fixing capacity and other characteristics. It has firmly established that leaching losses of K are reduced by liming. Peech and Bradfield (1943) concluded that it was unlikely that liming at moderate rates even for long period cause a significant revision of added or exchangeable K to non-exchangeable form and inhibited to some degree the release of exchangeable-K. On the other hand, liming strongly acid soil to pH 5.4 to above decreased, exchangeable K (MacLeod et al., 1964).

Kadrakar and Kibbe (1972) observed significant positive correlation between exchangeable, available and water soluble K_2O content and $CaCO_3$ in Mahermohtra soils. A significant positive correlation between available K content and $CaCO_3$ was observed in deep blacky red and yellow soils of Madhya Pradesh (Verma and Verma, 1968).

Powell and Hutcheson (1965) observed that wetting and drying cycles followed by liming reduced levels of exchangeable-K in soils containing micaceous minerals. Pearson (1958) enumerated four ways in which liming influences native and applied K in soils: (i) It may depress the uptake of soluble K, (ii) It may increase or decrease the rate of release of native soil non-exchangeable K, (iii) It tends to increase the rate of K fixation into less soluble form, and (iv) it decreases leaching losses of K.

The effect of liming on K-fixation and release is still not clear. Results reported in the literature can be quoted to show that effect ranges all the way from strongly repressing the conversion of non-exchangeable K into exchangeable form, to strongly favour it. Sarkunan et al. (1973) found no effect of $CaCO_3$ on K availability in south Arcot soils of Tamil Nadu.

Prasad et al. (1976) working on acidic red loams of Kanke long term experimentation indicated increase in exchangeable K content of the soil due to the application of lime and NPK fertilisers.

Calcium and Magnesium

Ca and Mg are more energetically bonded to permanent charge on soil colloides than to various weakly acid exchange spots, thus availability of Ca^{++} and Mg^{++} increased by liming (Coleman et al., 1959), as more calcium and magnesium move from lime particles to exchange sites (Sinha and Singh, 1966).

Khind et al. (1970) observed greater availability of Ca in Ca labelled lime in the Palampur acid soils. The effect of lime was more conspicuous on Ca than Mg (Roy, 1967). Helyer and Anderson (1974) reported that the liming of acid soils resulted in the increase of the availability of Ca, but they observed that there was little effect on the availability of other cations. Sinha et al. (1965) and Kothan Daraman and Mariakulandai (1965) found an appreciable increase in exchangeable Ca due to liming of acid soils of Chotta Nagpur. They also found that exchangeable Ca increased in the first year of lime application and then it decreased in subsequent years though it was still relatively at a higher level in lime treated soils as compared to untreated soils.

A definite rise in exchangeable Ca and Mg on application of dolomite in acidic soils of Chotta Nagpur have been reported by Sinha and Singh (1966). They further studied the effect of $Ca(OH)_2$ and $Mg(OH)_2$ on Ca and Mg content of acidic red loam soils of Kanke (Ranchi). A progressive rise in Ca and Mg, a decrease in exchangeable Mg was observed with increase in Ca addition. On the other hand, with increase in Mg^{++} addition, exchangeable Ca decreased while exchangeable Mg increased. Increase in the case of Ca or Mg, therefore, depends on the constituent elements of the liming material. Prasad et al. (1976) reported that application of lime increased exchangeablo Mg content of the soil.

CHAPTER -III

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

A detailed account of materials used and the methods followed in the investigation of "Effect of liming on the forms of P and other soil properties in an alfisol of Palampur (Himachal Pradesh)"are given in this chapter.

1. Field experiment

The field experiment was conducted at Bhadiarkhar research farm of Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, on paddy-wheat rotation during the Kharif season of 1982 under auspices of "All India Co-ordinated Agronomic Research Project." Lime was applied 15 days before transplanting to stabilise the soil pH to a desired level. The inorganic-P fertiliser was applied in the sub-plots at the time of transplanting. In the kharif season of second year one fourth of lime and full dose of P was applied to the main and subplots, respectively. But in the following rabi season only full dose of P was applied before the sowing of wheat crop. Uniform doses of N and K were applied @ 120 and 60 kg per hectare, respectively, in each plot to both the crops. The residual effect of liming was studied in wheat crop (Rabi season) 1983-84 only. The soil samples were collected before and after the crop and the yield was also recorded for the same season.

1.1 Site and location: Bhadiarkhar research station is about 5 km from the university campus and is situated at $32^{0}6'$ N latitude and 76.3^{0}C longitude, has an altitude of 1180 m above mean sea level. The area lies in the Kangra valley of Himachal Pradesh at the foot of Dhauladhar hill ranges of great Himalaya and represents high rainfall mid-hill zone of Himachal Pradesh.

1.2 Climate and weather conditions: Climate of this place is sub-temperate humid with moderately hot summer and severe cold winter. Rainfall is very high averaging about 2500 mm annually. 62 per cent of the total rainfall is received in the months of July to September. The mean relative humidity varies from 45.6 to 84.6 per cent, the minimum being in May and maximum in July.

1.3 Soils: The soils in Palampur region are acidic in reaction with silt loam to clay loam in texture. The soils have been developed under the dominant process of podzolisation and genetically classified as grey brown podzols. According to the 7th Approximation system these soils are classified in the order alfisol with typic hapludalfs as subgroup. The rocks to which the soils of this area owe their origin are slates, phyllites, quartzites, schists and gneisses. Some physico-chemical properties of the soils of experimental site determined at the initiation of the experiment are given in the following table.

Table 1. Physico-chemical properties of the soils of experimental site

Soil properties	Average value
Mechanical composition	
Sand (%)	22.7
Silt (%)	47.4
Clay (%)	23.5
Textural class	Silt loam
pH	5.60
Organic carbon (%)	0.95
Available N (kg/ha)	531.4
Available P (kg/ha)	16.9
Available K (kg/ha)	324.2

The particulars of experiment are as under:

Year of start : 1982-83

Design : Split plot design with lime in main plots and P-levels in subplots.

No.of replications : Four

Total No.of plots : Forty-eight.

The present study include only collection of plant and soil samples from Rabi 1983-84 with the following treatments:

a) Lime levels (Main plots)

L_0 = Control (original pH)
L_1 = 1.25 t/ha
L_2 = 2.50 t/ha
L_3 = 5.50 t/ha

b) Phosphorus levels (sub-plots)

P_0 = Control
P_1 = 45 kg/ha
P_2 = 90 kg/ha

2. Source of nutrients

Nitrogen, phosphorus, potash were applied through CAN, superphosphate and muriate of potash, respectively.

3. Methods

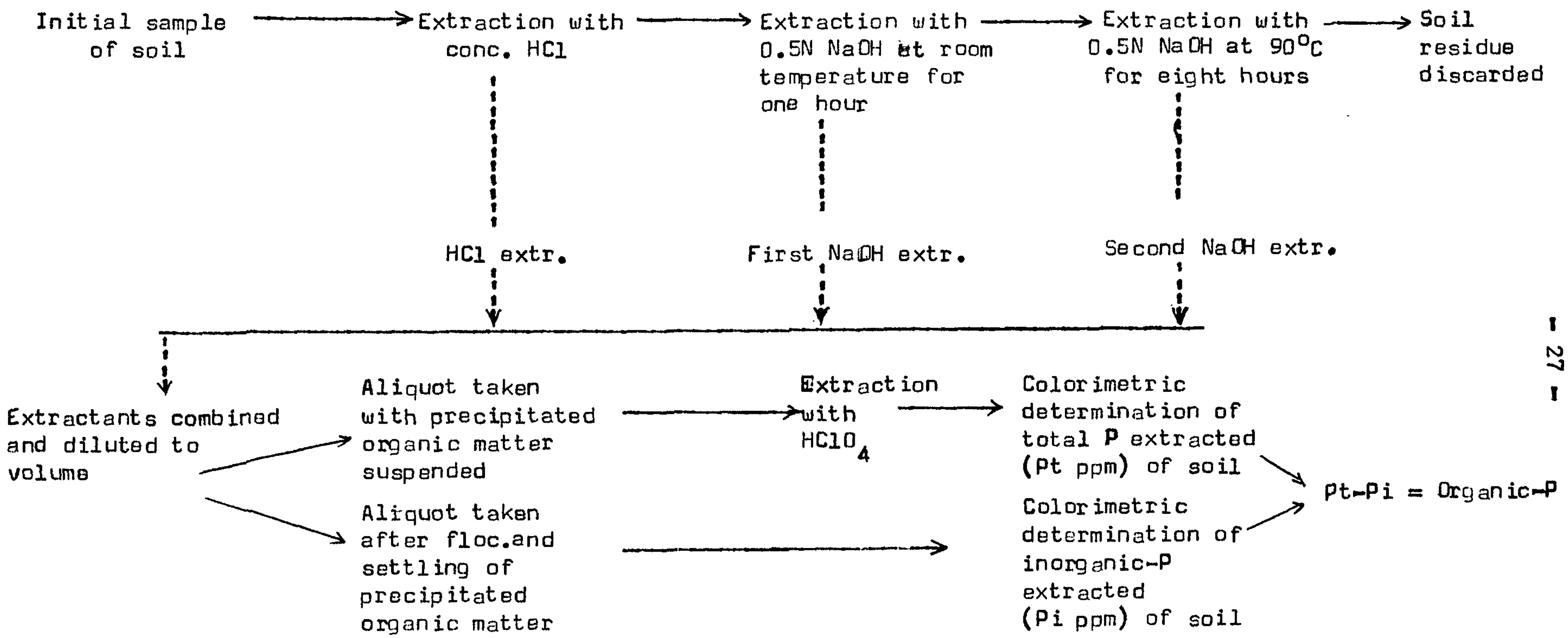
3.1 Collection and preparation of soil samples: The representative soil samples from two depths 0-15 and 15-30 cm from individual plots were collected for the study before sowing and after harvest of wheat crop during Rabi 1983-84 Also the crop produce samples viz., grain and straw from individual treatment (plot) were collected after the harvest of crop. These samples were then air-dried, ground and stored in the polythene bags for analytical work.

3.2 Methods of analysis: Soil samples collected were analysed for soil pH, organic carbon, available N, P, K, inorganic P-fractions, organic phosphorus, exchangeable cations and exchangeable acidity. The plant samples were analysed only for total P. The standard methods used for the soil and plant analysis are given below:

Table 2

Sr. No.	Determination	Method followed
1.	<u>Soil Analysis</u>	
	a) Sand, silt and clay content (mechanical fractions)	International pipettee method (Piper,1966)
	b) pH (1:2.5 soil water ratio)	Glass electrode pH meter (Jackson, 1973).
	c) Organic carbon	Rapid titration method (Walkley and Black, (1934).
	d) Available nitrogen	Alkaline permanganate method (Subbiah and Asija, 1956).
	e) Available phosphorus	Method of Olsen <u>et al</u>. (1954).
	f) Available potassium	Method of Hanway and Heidal (1952) by flamephotometer.
	g) Inorganic-P fractions (saloid-P, Fe-P, Ca-P,Al-P)	Method of Chang and Jackson (1957) modifie by Peterson and Correy (1966).
	h) Exchangeable Ca^{++} and Mg^{++}	EDTA-titration method (Black, 1965).
	i) Exchangeable Na^{+}	Flamephotometrically
	j) Exchangeable acidity	Barium chloride triethanolamine method (Peech <u>et</u> <u>al</u>., 1962).
	k) Organic-P determination	The organic-P in soils was determined by successive extractions with concentrated HCl and then with 0.5N NaOH at room temperature for one hour and 0.5N NaOH at 90°C for 8 hours as given by Mehta <u>et</u> <u>a</u> (1954). The difference in content of inorganic and total phosphorus in the combined extracts was taken as total organ phosphorus in the soil. The total P and inorganic P were determined colorimetrical as inorganic-P by Olsen's method (Aliquot taken after flocculation and settling of precipitated organic matter). While aliquot with precipitated organic matter suspended is digested with $HClO_4$ for determining the total P. (The details for the determination of organic-P are given in the flow-sheet on the next page).

Flow sheet for the determination of organic-P (Mehta et al., 1954)



2. Plant analysis

A known weight of the ground plant samples was digested as per wet digestion method (Lee, 1966) and phosphorus was determined by the following method:

Phosphorus	Vanado-molybdate method (Jackson, 1973).

4. Statistical Analysis

For evaluating the effect of various treatments on the yield of wheat, P-uptake and other soil properties with their interaction effects were analysed according to the statistical methods suggested by Steel and Torrie (1968).

CHAPTER-IV

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

Results pertaining to the residual effect of lime and direct effect of P on plant growth and soil properties are presented under the following heads:

I. Yield and P-uptake by wheat

II. Relationship of P fractions with yield and P uptake.

III. Available content of major nutrients in soil before and after the crop.

IV. Exchangeable calcium and magnesium, pH, organic carbon and CEC before the after the crop.

I. Yield and P-uptake by wheat

The perusal of data revealed that grain yield was increased significantly by lime application from 32.75 q/ha at L_0 to 45.57 q/ha at L_3 by about 39.1 per cent (Table 1). However, the lime doses L_1, L_2 and L_3 were at par with each other. Lime levels did not show any significant effect on straw yield. The total P-uptake was increased significantly to the extent of 42.6 per cent with its value 17.49 kg /ha at L_0 and 24.95 at L_3 level.

Grain as well as straw yield was also increased significantly with each level of P and it was to the extent of 48.3 and 32.0 per cent, respectively, by the addition of P_2 level of P. Total P uptake was also increased significantly from 17.05 to 26.29 kg/ha to the extent of 54.2 per cent due to P_2 over P_0 level of applied P. The increase in P uptake was only 34.5 per cent with first dose of P application.

There was significant interaction between different levels of lime and P in influencing the grain yield. At the same level of P, the increasing levels of lime increased the grain yield from 18.10 to 39.4 q/ha

Table 1. Residual effect of lime and direct effect of P on the yield and P-uptake of wheat (S-308)

	Yield (q/ha)		Total P-uptake (kg/ha)
	Grain	Straw	
a) Effect of lime levels			
L_0	32.75	59.08	17.49
L_1	44.48	69.17	24.23
L_2	40.29	68.23	21.68
L_3	45.57	68.48	24.95
C.D. 5%	8.99	N.S.	4.10
b) Effect of P-levels			
P_0	31.93	56.21	17.05
P_1	43.04	67.74	22.93
P_2	47.34	74.77	26.29
C.D. 5%	3.11	4.96	2.13

c) Interaction effect of LxP on grain yield (q/ha)

P-levels	Lime levels			
	L_0	L_1	L_2	L_3
P_0	18.10	38.63	31.60	39.40
P_1	37.62	47.56	40.34	46.65
P_2	42.52	47.25	48.93	50.65

C.D. 5% between two:

(i) L means at same level of P = 7.71

(ii) P means at same level of L = 6.22

i.e., upto 117.7 per cent due to L_3 over L_0. At P_1 and P_2 levels of P the increase due to lime application was very little that is only upto 24.0 per cent in P_1 and 19.1 per cent in P_2. However, at the same level of lime the effect of different levels of P was more prominent at L_0 level then at L_1, L_2 and L_3 levels of lime. The increase was to the tune of 134.9 per cent at L_0, 22.7 per cent at L_1, 54.8 per cent at L_2 and 28.5 per cent at L_3 levels of lime with the maximum (90 kg P_2O_5/ha) dose of phosphorus. Generally, L_1, L_2 and L_3 doses were at par among each other with same level of either P_0 or P_1 or P_2 levels of P-application.

II. Relationship of P fractions with yield and P uptake

The correlations studies given in Table 2 (i) reveals that grain yield and P uptake was significantly and positively correlated with saloid-P, Al-P, Fe-P, Ca-P, organic-P and total P of the soil. The per cent contributior of saloid and organic P towards grain yield was to the extent of 72 per cent by the both fractions and was maximum, and that of Fe-P was minimum i.e., 42 per cent.

The Olsen-P also showed a positive relationship with grain yield and P-uptake and it contributed towards grain yield and P uptake upto 74 per cent. There was also a relationship of all the P-fractions with Olsen P, and all the inorganic-P fractions showed their contribution from 79 to 88 per cent towards Olsen's P fraction (available P). However, the organic-P contribution was much less i.e., 56 per cent only (Table 2, ii) as compared to other inorganic-P fractions.

III. Available content of major nutrients in soil before and after the crop

Results for available P, P-fractions, available nitrogen and potassium are given below:

Table 2. Correlation studies

i) Simple correlation coefficients (r) of grain yield and P-uptake with P-fractions

Dependent variable	Independent variable			
	Grain yield		P-uptake	
	r	r^2	r	r^2
Saloid-P	0.85	0.722	0.84	0.706
Al-P	0.72	0.518	0.72	0.518
Fe-P	0.67	0.448	0.65	0.423
Ca-P	0.79	0.621	0.80	0.640
Organic P	0.85	0.722	0.71	0.504
Total P	0.80	0.640	0.80	0.640
Olsen P	0.86	0.740	0.86	0.740

ii) Relationship of Olsen P with other P fractions

		Saloid-P	Al-P	Fe-P	Ca-P	Organic P
Olsen P	r	0.94	0.91	0.90	0.93	0.75
	r^2	0.884	0.825	0.810	0.865	0.563

i) Available P and P fractions

a) Available P

Results presented in Table 3 showed that available P in 0-15 cm depth was significantly increased with increasing levels of lime both before and after the wheat crop. In the former case, in case of no lime application its content was 16.62 kg/ha the lowest, it was increased by 28.7, 53.1 and 87.2 per cent, respectively due to L_1, L_2 and L_3 levels of lime. In the latter case lowest content was 21.28 kg/ha in case of no lime application which was observed to increase by 57.3, 72.1 and 125.9 per cent, respectively by the above said increasing levels of lime. Almost similar trend was found in 15-30 cm depth both before and after the crop. Before crop the lowest content of 18.23 kg/ha was observed in case of L_1 level of lime which was statistically at par with 18.29 kg/ha in case of no lime application. An increase of 9.2 and 25.5 per cent respectively due to application of L_2 and L_3 over L_0 was recorded in this depth before the crop. After the crop lowest content of available P 18.97 kg/ha, in case of no lime application was noted, over which increase of 15.1, 32.3 and 71.7 per cent due to different increasing levels of lime were found.

Available P was also significantly increased to a large extent due to the application of increased levels of phosphorus in 0-15 cm and 15-30 cm depth both before and after the crop (Table 3). In the upper depth, the lowest content of 17.23 kg/ha was recorded in case of P_0 application over which increase of 34.7 and 83.3 per cent due to P_1 and P_2 levels of P were found before the crop. In this depth after the crop the lowest content of 21.59 kg/ha in case of no phosphorus application was noted and increase of 67.8 and 98.3 per cent, respectively , due to P_1 and P_2 levels of phosphorus were observed.

Table 3. Residual effect of lime and direct effect of P on available P (kg/ha) status of soil

	Available P (kg/ha)			
	0-15 cm		15-30 cm	
	Before crop	After crop	Before crop	After crop
a) Effect of lime levels				
L_0	16.62	21.28	18.29	18.97
L_1	21.64	33.47	18.23	21.83
L_2	25.75	36.68	19.97	25.19
L_3	31.49	48.07	22.95	32.57
C.D. 5%	2.11	2.48	1.42	3.06
b) Effect of P levels				
P_0	17.23	21.59	17.20	20.01
P_1	23.24	36.23	19.89	26.06
P_2	31.66	42.81	25.54	28.49
C.D. 5%	2.11	2.30	0.42	0.87

c)i) Interaction effect of LxP on available P before sowing of wheat

P-levels	Lime levels							
	L_0		L_1		L_2		L_3	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
P_0	12.95	16.24	16.24	16.80	19.04	17.36	20.72	18.43
P_1	16.80	17.41	21.28	19.04	24.08	20.72	30.80	22.40
P_2	22.07	21.28	27.44	19.04	34.16	21.84	42.98	28.00

C.D. 5% between two:

	0-15cm	15-30cm
(i) L means at same level of P =	3.72	1.15
(ii) P means at same level of L =	4.23	0.85

ii) Interaction effect of LxP on available P after harvesting

P-levels	Lime levels							
	L_0		L_1		L_2		L_3	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
P_0	9.52	17.06	21.44	19.61	28.56	21.84	35.83	25.76
P_1	25.76	20.72	34.16	21.28	36.83	25.76	48.16	32.48
P_2	28.56	21.84	38.80	24.64	44.67	28.00	59.22	39.49

C.D. 5% between two:

	0-15 cm	15-30cm
(i) L means at same level of P =	4.09	2.44
(ii) P means at same level of L =	4.61	1.75

Significant interaction between levels of lime and levels of P with regard to content of available P in 0-15 cm depth, both before and after the crop was observed (Table 3). At the same levels of P the increasing levels of lime resulted in significant increase in available P except between L_1 and L_2 at P_1 level of phosphorus before the crop. However, the maximum (94.1%) increases in available P due to increased levels of lime was observed at P_2 level of applied phosphorus. Similarly at the same level of lime the increasing levels of P resulted in an increase in the available P except between P_0 and P_1 in case of no lime application and the maximum (107.4%) increase in available P resulted at L_3 level of lime due to P_2 level of applied phosphorus. Trend of interaction between different levels of lime and P in 0-15 cm layer after harvest of crop with regard to available P was almost similar as was observed before the crop. At the same level of P the increasing levels of lime resulted in an increase of available P, the maximum (276.3%) at L_3 P_0 level and the minimum (86.9%) at P_1 level of applied P. But, at P_1 level of phosphorus no significant difference between L_1 and L_2 levels of lime was observed. At the same level of lime the increased levels of P resulted in an increase in available P, except between P_1 and P_2 at L_0 and L_1 levels of lime, the maximum increase of 200.0 per cent at L_0 level of lime was observed.

In 15-30 cm depth also interaction between levels of lime and phosphorus in influencing the content of available P was significant both before and after the crop. At the same level of P, there was significant increase in the content of available P due to increasing levels of lime in general, before the crop. However, at P_0 levels, no significant difference between L_0 & L_1 and L_2 & L_3 levels of lime and at P_1 level of phosphorus among L_C, L_1 and L_2 levels of lime and at P_2 level of phosphorus between L_0 and L_1 was noted. At P_2 level of phosphorus the maximum increase of 31.6 per cent due to L_3 over L_0 level of lime was recorded. At the same level of lime the increasing levels of phosphorus resulted in significant increase in available P content except at L_1 level of lime where no significant difference between P_1 and P_2 was observed. The maximum increases of 21.5 per cent due to P_1 over P_0 and 51.9 per cent of P_2 over P_1 at L_3 level of lime was seen. After the crop, at the same level of phosphorus the increasing levels of lime resulte in significant increase in available P except that no difference between L_1 and L_2 at P_0 level of phosphorus and L_0 and L_1 at P_1 level of phosphorus was noted. At P_2 level of phosphorus the maximum increase of 88.8 per cent due to L_3 over L_0 level of lime was seen. At the same level of lime there was significant increase in available P due to increase in levels of phosphorus except that no difference between P_1 and P_2 at L_0 level of lime was noted. In this case also the maximum increase of 26.1 per cent due to P_1 over P_0 and 53.3 per cent due to P_2 over P_1 at highest i.e., L_3 level of lime was recorded.

b) P-fractions

In 0-15 cm depth the highest value for organic-P and lowest for saloid-P at different levels of lime as well as phosphorus (81.25 and 2.15 ppm before the crop and 119.49 and 2.46 ppm after the crop) were recorded (Table 4). Fe-P fraction was found to be dominant among inorganic P fractions, followed by Ca-P and Al-P. The Al-P fraction showed maximum increase in its fraction with increasing levels of lime. And it was to the extent of 77.9 per cent before the crop and 100.1 per cent after the crop due to L_3 over L_0 level of lime. The increase in organic-P due to lime levels was very little as compared to other fractions, except at L_3 level where it was 36.2 per cent

Table 4. Residual effect of lime and direct effect of P on P-fractions of the soil

	P-fractions (ppm) 0-15 cm depth											
	Saloid-P		Al-P		Fe-P		Ca-P		Org-P		Total P	
	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop
a) Effect of lime levels												
L_0	1.78	2.18	5.35	6.54	28.56	38.44	8.92	11.30	78.00	112.33	625.00	657.00
L_1	2.18	2.46	7.73	9.52	33.32	41.66	11.30	14.88	76.66	110.67	645.00	657.00
L_2	2.18	2.46	8.35	10.90	38.08	44.38	11.90	16.66	84.00	117.67	619.00	624.00
L_3	2.46	2.74	9.52	13.09	39.62	53.56	13.69	19.04	84.66	153.00	640.00	657.00
b) Effect of P levels												
P_0	1.78	2.29	5.00	8.48	31.24	40.44	9.37	12.50	58.25	87.00	498.00	514.00
P_1	2.23	2.44	7.59	10.71	34.82	45.42	11.16	15.18	81.00	109.00	672.00	670.00
P_2	2.44	2.65	9.82	11.60	38.64	47.58	13.84	18.75	100.25	174.25	727.00	763.00

after the crop. All the P fractions were found to increase with increasing levels of lime, the maximum percentage increase in Al-P (100.1% after the crop) and the minimum in saloid-P (38.2% before crop and 25.7% after crop) due to L_3 over L_0 of lime. Total P did not increase with liming both before and after the crop and its value remained almost constant (Fig. 1).

The effect of P in increasing the different fractions of P was maximum (100.3%) in case of organic P fraction followed by Al-P (69.3%), Ca-P (50.0%), Fe-P (17.7%) and lastly by saloid-P (15.7%). Increasing levels of P have also shown a pronounced increase in total P content and its value increased to the extent of 45.9 per cent and 48.4 per cent in both before and after the crop, respectively (Fig. 1).

The build up of organic P fraction was more prominent due to application of P rather than the application of lime. However, the effect of added P as well as of lime was to the same extent in case of Ca-P. The Fe-P contents increased to lesser extent i.e., 23.69 per cent and 17.66 per cent before and after the crop, respectively, due to P-application. Al-P increased 69.3 per cent and 36.7 per cent, respectively before and after the crop, due to P_2 level of P application.

ii) Available N

The available N content was significantly increased with increase in levels of lime in both, 0-15 and 15-30 cm depth before and after the crop (Table 5). In the former layer the content of available N before the crop was 459.94 kg/ha and after the crop 482.94 kg/ha. The increase in the first value was 25.4 per cent due to L_2 over L_0 (with no significant difference among L_1, L_2 and L_3) and in the second value 26.2 per cent at L_3 over L_0. In the second depth, the highest increase before the crop was

Table 5. Residual effect of lime and direct effect of P on the available N status of soil

	Available N (kg/ha)			
	0-15 cm		15-30 cm	
	Before crop	After crop	Before crop	After crop
a) Effect of lime levels				
L_0	459.94	482.94	569.49	564.47
L_1	543.56	516.39	647.63	650.85
L_2	576.59	572.93	634.84	636.45
L_3	545.65	609.68	636.83	649.26
C.D. 5%	51.01	22.28	29.64	25.06
b) Effect of P levels				
P_0	499.85	503.31	629.18	653.52
P_1	545.63	537.44	623.60	625.13
P_2	548.79	536.06	613.82	602.21
C.D. 5%	28.79	N.S.	N.S.	16.37

c) Interaction effect of LxP on available N after the crop

P-levels	Lime levels							
	L_0		L_1		L_2		L_3	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
P_0	439.03	-	533.12	-	633.76	-	647.34	-
P_1	501.76	-	501.77	-	534.59	-	611.65	-
P_2	508.02	-	514.30	-	558.20	-	570.74	-

C.D. 5% between two:	0-15cm	15-30cm
(i) L means at same level of P =	46.12	-
(ii) P means at same level of L =	53.76	-

13.7 per cent in L_1 over L_0 and after the crop 15.3 per cent in L_1 over L_0, whereas no significant difference in increasing due to L_1, L_2 and L_3 over L_0 was seen before and after the crop.

Due to different levels of phosphorus the available status of N, in general, was increased with increase in levels of P in the 0-15 cm depth. The available N was increased by 9.8 per cent due to P_2 over P_0 with non-significant difference among different levels of P after the crop. In the second depth available N was not influenced significantly due to different levels of P before the crop but it was decreased from 653.52 kg/ha by 4.5 per cent and 8.5 per cent due to P_1 and P_2, respectively over P_0 after the crop.

Interaction between different levels of lime and phosphorus after the crop was significant in 0-15 cm depth. At P_0 the increase due to L_1 and L_2 levels of lime was significantly higher than the preceding lower levels of lime, but there was significant difference between L_2 and L_3. At P_1 there was significant difference between L_0, L_1 and L_2 levels of lime but available N was significantly higher at L_3 (611.65 kg/ha) than at other levels of lime. At P_2 the available N due to two neighbouring levels of lime did not differ whereas there was significant difference between L_0 & L_2 and L_1 & L_3. At the same level of lime variation in available N due to different levels of P was non-consistent. At L_0 level of lime there was significant increase (15%) in available N at P_1 over P_2. At L_1 and L_2 levels of lime no significant variation due to different levels of P was observed. And at L_3 level, no difference in available N due to P_0 & P_1 and P_1 & P_2 was recorded but available N was significantly decreased (11.8 per cent) due to P_0 and P_2.

iii) Available K

Average content of available K due to different levels of lime in 0-15 cm depth was 324.15 kg/ha and 319.75 kg/ha before and after the crop respectively, and the corresponding values for 15-30 cm depth were 255.75 and 247.45 kg/ha (Table 6). Significant difference in available K of 15-30 cm depth only after the crop was noted at different levels of lime except between L_1 and L_2.

The average content of available K due to different levels of phosphorus in 0-15 cm depth were 323.77 and 317.50 kg/ha before and after th crop whereas the corresponding values for 15-30 cm depth were 255.83 and 242.67 kg/ha. Available K did not differ due to different levels of phospho except that in 15-30 cm depth it decreased from 230.0 kg/ha at P_0 by 9.8 and 6.7 per cent respectively at P_1 and P_2 levels of phosphorus after the crop.

IV. Exchangeable calcium and magnesium, pH, organic carbon and CEC before and after the crop

i) Calcium and magnesium

Exchangeable Ca^{++} as influenced by different levels of lime increased significantly due to increased levels of lime only after the crop (Table 7). The minimum value of 2.60 me/100g soil at L_0 was increased by 62.7 per cent to 4.23 me/100g soil at L_3 before the crop and the corresponding values at the corresponding levels of lime after the crop was 2.25 me/100g soil increased by 103.1 per cent to a value of 4.57 me/100g soil. Exchangeable Mg^{++} both before and after the crop was not affected by the increase in levels of lime.

Table 6. Residual effect of lime and direct effect of P on the available K status of soil

	Available K (kg/ha)			
	0-15 cm depth		15-30 cm depth	
	Before crop	After crop	Before crop	After crop
a) <u>Effect of lime levels</u>				
L_0	313.6	296.5	258.5	268.0
L_1	321.0	317.0	254.5	252.5
L_2	328.5	324.5	255.5	242.5
L_3	333.5	341.0	254.5	228.0
C.D. 5%	N.S.	N.S.	N.S.	14.0
b) <u>Effect of P levels</u>				
P_0	331.5	330.5	257.5	230.0
P_1	321.0	313.5	254.0	252.5
P_2	318.8	308.5	256.0	245.5
C.D. 5%	N.S.	N.S.	N.S.	7.27

Table 7. Residual effect of lime and direct effect of P on exchangeable cations (Ca^{++}, Mg^{++})

	Exchangeable cations (me/100g soil)			
	0-15 cm			
	Calcium		Magnesium	
	Before crop	After crop	Before crop	After crop
a) Effect of lime levels				
L_0	2.60	2.25	1.58	1.39
L_1	3.23	3.25	1.50	1.42
L_2	2.88	3.82	1.60	1.52
L_3	4.23	4.57	1.58	1.33
C.D. 5%	0.23	0.07	N.S.	N.S.
b) Effect of P levels				
P_0	3.26	3.17	1.51	1.41
P_1	3.16	3.47	1.43	1.36
P_2	3.29	3.80	1.49	1.42
C.D. 5%	N.S.	0.07	N.S.	N.S.

c) Interaction effect of LxP on exchangeable calcium

P-levels	Lime levels							
	L_0		L_1		L_2		L_3	
	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop
P_0	2.5	2.0	2.9	3.1	3.7	3.6	4.1	4.0
P_1	2.6	2.2	3.2	3.2	2.6	3.8	4.3	4.7
P_2	2.8	2.6	3.7	3.5	2.3	4.1	4.4	5.0

C.D. 5% between two:

		Before crop	After crop
(i) L means at same level of P	=	0.35	0.13
(ii) P means at same level of L	=	0.39	0.15

Exchangeable Ca^{++} and Mg^{++} were not influenced by the increase in P-levels before the crop. However, exchangeable Ca^{++} after the crop was increased from 3.17 me/100g soil at P_0 by 19.9 per cent to 3.8 me/100g soil at P_2 level of phosphorus, whereas exchangeable Mg^{++} was remained almost the same.

There was a significant interaction between different levels of lime and phosphorus influencing the amount of exchangeable calcium in the soil both before and after the crop. Before the crop the amount of exchangeable Ca^{++} was increased significantly by increase in levels of lime at the same level of phosphorus except that at P_1 and P_2 levels of P in exchangeable Ca^{++} due to decrease in its amount at L_2 to the amount at L_1 was not significant. Per cent increase in the amount of exchangeable Ca^{++} was the maximum (65.3 per cent) at P_0 level due to L_3 level of lime but otherwise the total amount of exchangeable Ca^{++} due to L_3 at P_2 level of phosphorus was maximum (4.4 me/100g soil). Exchangeable calcium was significantly decreased (38.0%) at L_2 due to increase in levels of phosphorus vis-a-vis no significant increase at L_0 and L_3 due to increase in levels of P, at L_1 due to increase in P levels from P_0 to P_1 was noted. Increase in exchangeable Ca^{++} with increase in levels of lime at the same levels of phosphorus after the crop showed exactly the similar trend, no doubt different in magnitude and so was true with regard to variation in exchangeable calcium with the increase in levels of P at the same level of lime.

ii) Soil pH

Data given in Table 8 showed that the pH values influenced by different levels of lime both before and after the crop. In 0-15 cm layer the lowest (5.1) pH value at L_0 was increased by 1.2 units at L_3 before the

Table 8. Residual effect of lime and direct effect of P on pH, organic carbon and CEC of the soil

	pH				(%) O.C.				CEC (me/100g soil)	
	0-15 cm		15-30 cm		0-15 cm		15-30cm		0-15 cm	
	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop	Before crop	After crop
a) Effect of lime levels										
L_0	5.1	5.3	5.3	5.4	0.93	0.98	0.97	0.98	9.54	8.70
L_1	5.2	5.6	5.4	5.7	0.94	1.03	1.00	1.03	9.82	9.34
L_2	5.6	5.9	5.7	5.9	0.96	1.05	1.01	1.07	7.92	9.72
L_3	6.3	6.4	5.9	6.0	0.97	1.11	1.02	1.11	8.75	10.08
C.D. 5%	-	-	-	-	N.S.	0.009	0.005	0.009	0.58	0.70
b) Effect of P levels										
P_0	5.5	5.7	5.5	5.7	0.94	1.03	0.99	1.03	9.90	9.44
P_1	5.5	5.8	5.5	5.8	0.95	1.04	1.00	1.04	8.84	9.01
P_2	5.6	5.9	5.6	5.9	0.84	1.07	1.01	1.06	8.28	9.93
C.D. 5%	-	-	-	-	0.007	0.004	0.004	0.004	0.36	0.59

c) Interaction effect of LxP on (%) O.C. after the crop

	Lime levels							
	L_0		L_1		L_2		L_3	
P-levels	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
P_0	0.97	0.98	1.01	1.02	1.05	1.06	1.09	1.09
P_1	0.98	0.98	1.03	1.03	1.06	1.06	1.10	1.11
P_2	0.99	0.99	1.05	1.04	1.09	1.10	1.16	1.13

C.D. 5% between two:		0-15cm	15-30cm
(i) L means at same level of P	=	0.009	0.009
(ii) P means at same level of L	=	0.009	0.008

crop similarly the corresponding increase in pH value at L_0 from 5.3 to 6.4 at L_3 after the crop was noted. In 15-30 cm layer the lowest pH valu of 5.3 at L_0 was increased to 5.9 at L_3 before the crop and after the crop from 5.4 to 6.0 at given levels of lime (Table 8).

Soil pH, in general, was also increased due to increase in levels of phosphorus. In 0-15 cm layer before the crop pH was increased from 5.5 at P_0 to 5.6 at P_2 and after the crop from 5.7 to 5.9 at the given levels of phosphorus. In 15-30 cm layer before the crop it was increased from 5.5 at P_0 to 5.6 at P_2 and after the crop from 5.7 at P_0 to 5.9 at P_2.

iii) Organic carbon

Per cent organic carbon, on the whole, was significantly increased due to increased levels of lime. However, in 0-15 cm depth it did not diffe significantly with levels of lime before the crop but was increased from 0.98 per cent at L_0 to 1.11 per cent at L_3. In the lower depth its content increased from 0.97 per cent at L_0 to 1.02 at L_3 before the crop and 0.98 per cent at L_0 to 1.11 per cent at L_3 after the crop (Table 8).

The content (%) of organic carbon was influenced significantly by different levels of phosphorus in the first layer , it decreased from 0.94 per cent at P_0 to 0.84 per cent at P_2 before the crop and increased fro 1.03 per cent at P_0 to P_2 1.07 per cent at P_2 after the crop. In the second layer its content increased from 0.99 per cent to 1.01 per cent at P_2 before the crop and from 1.03 per cent at P_0 to 1.06 per cent at P_2 after the crop.

Interaction between different level of lime and P influencing the content of organic carbon in both the layers after the crop was significant

In the upper layer the organic carbon content was statistically similar with increase in levels of lime upto L_2 at constant levels of P either at P_0 or P_1. But it was increased from 0.97 per cent at L_0 to 1.09 per cent at L_3 with P_0 as constant level of phosphorus, and from 0.98 per cent at L_0 to 1.1 per cent at L_3 with P_1 at the constant level of phosphorus. At P_2 level of phosphorus, the organic carbon content increased significantly from 0.99 per cent at L_0 to 1.09 per cent at L_2 and 1.16 per cent at L_3 with non-significant difference between the related values. At the same level of lime there was significant increase in the content of organic carbon with increase in the level of phosphorus but the magnitude was less at L_0 (0.97 to 0.99%) and went on increasing upto L_3 (1.09 to 1.16%) as the constant levels of lime.

In the second depth at the same levels of P the increase in the organic carbon content with increase in levels of lime showed practically the similar trend as was observed in the upper layer. The minimum value at L_0 and maximum value at L_3 while keeping either of P_0 or P_1 or P_2 as the constant level of phosphorus separately, were 0.98 and 1.09 per cent, 0.98 and per cent and 0.99 and 1.13 per cent, respectively. At the constant levels of lime the content of organic carbon increased significantly with increase in levels of phosphorus but the magnitude was lower at L_0 (0.98 to 0.99%) and the highest at L_3 (1.09 to 1.13%).

iv) Cation exchange capacity (CEC)

In 0-15 cm depth the CEC at L_0 was 9.54 me/100g soil with no significant difference, with CEC at L_1 but it decreased significantly to 8.75 me/100g soil at L_3 before the crop. After the crop it was 8.70 me/100g soil at L_0 which was statistically at par with CEC at L_1. The CEC at L_2

(9.72 me/100g soil) and L_3 (10.08 me/100g soil) no doubt, was statistically at par, but significantly higher than earlier two values (Table 8).

The CEC was decreased significantly with increase in levels of phosphorus from P_0 (9.90 me/100g soil) to P_2 (8.28 me/100g soil) before the crop, whereas after the crop it was 9.44 me/100g soil at P_0 with no significant difference with the value at P_1 (9.01 me/100g soil) and P_2 (9.93 me/100g soil) levels of P.

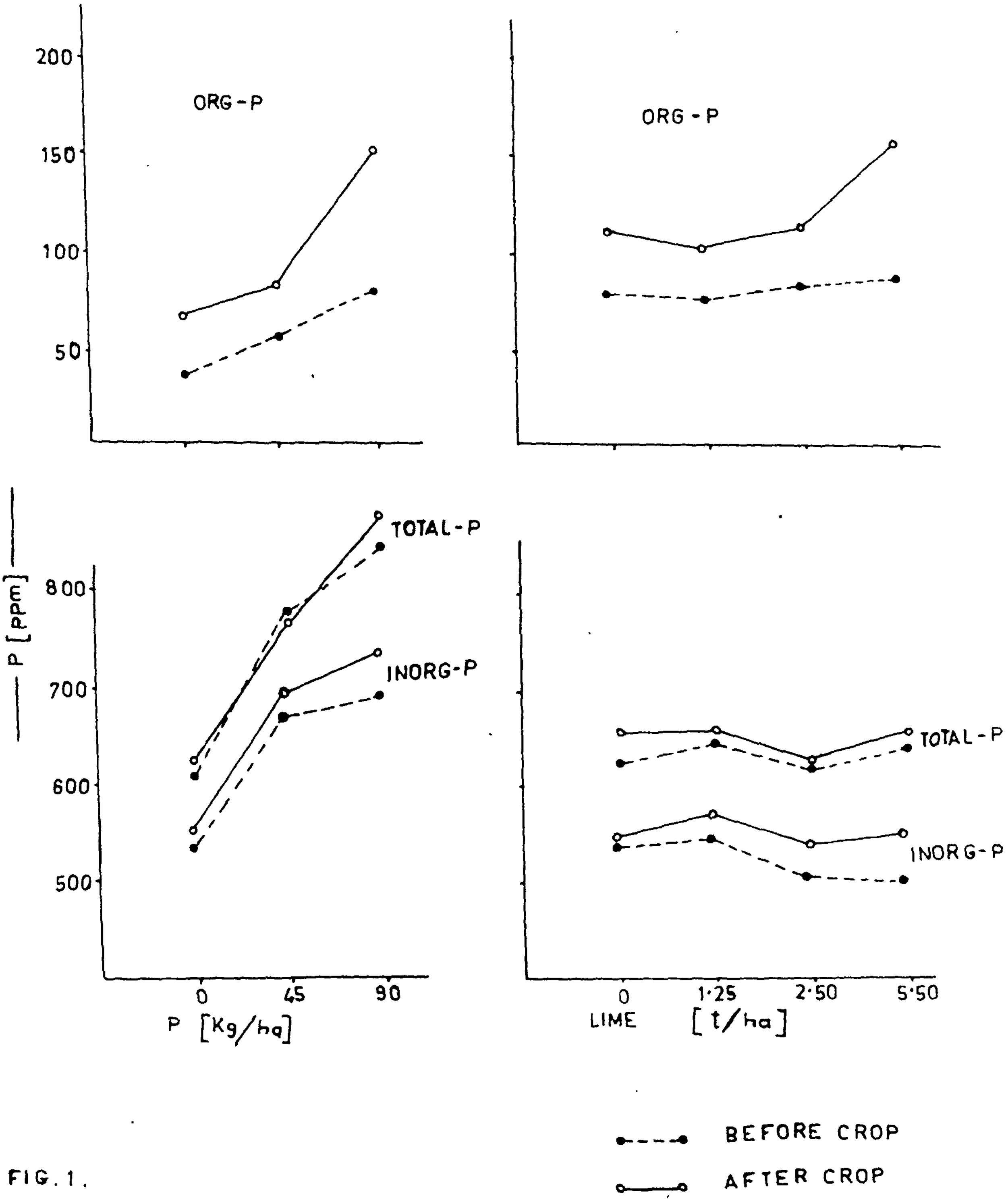


FIG. 1.

Residual effect of lime and direct effect of P on total, inorganic and organic phosphorus before and after the crop.

CHAPTER-V

DISCUSSION

CHAPTER-V

DISCUSSION

The present study was undertaken with an aim to investigate the changes taking place in a) inorganic-P fractions and organic-P fractions, b) chemical properties of soil, c) P uptake by wheat crop, d) relationship of yield with above said P fractions due to residual effect of lime and direct effect of phosphorus. The results, thus obtained, presented in the preceding chapter, have been discussed in this chapter.

Grain yield was increased significantly by lime application (1.25 t/ha to 5.5 t/ha) from 32.75 q/ha at 1.25 t/ha of lime, to 45.57 q/ha at 5.5 t/ha of lime by about 39 per cent. This may be attributed to the substantial increase in pH from 5.1 to 6.4 (Table 8) which might have been responsible for increase in the availability of different nutrients otherwise present in the unavailable forms like P, Cu, B, Zn, Mo etc., due to lower pH. This is substantiated by the appreciable increase in available P from 16.82 kg/ha at no lime application before the crop to 48.07 kg/ha at 5.5 t/ha of lime application after the crop (Table 3). This is corroborated by the fact that P-uptake significantly increased from 17.49 kg/ha at no lime application to 24.95 kg/ha at 5.5 t/ha level of lime. The increase in yield might be due to possible decrease in exchangeable Al as pointed out by Pradhan and Khera (1976). Mathur et al. (1985) while working on lime as a source of fertiliser in red loam soils of Bihar in their three years experiment observed that the highest mean yields of groundnut, soybean, gram and barley were obtained with full dose of (28.5-55.0 q/ha) lime on the surface. Similar results were reported by Lutz and Jones (1975) that there was increase in the yield and protein content of soybean.

Grain as well as straw yield was also significantly increased from 31.93 and 56.21 q/ha at no P-application to 42.34 and 79.77 q/ha at 90 kg P_2O_5/ha application. This may be attributed to again appreciable increase in available P from 17.23 kg/ha at no P application before the crop to 42.81 kg/ha after the crop with 90 kg P_2O_5/ha level of P. This is further supported by the fact that P-uptake increased from 17.05 kg/ha at no phosphorus application to 26.29 kg/ha at the maximum level of P applied. Similar results were reported by Porticles and Mojena (1979) that dry matter yield of Pangola grass pasture with application of single superphosphate @ 100-300 kg/ha P_2O_5 increased significantly.

Interaction between different levels of lime and P was significant in increasing the yield. At the same level of P then was significant increase in yield due to liming over no liming at no phosphorus and 45 kg/ha of P_2O_5, but at 90 kg P_2O_5/ha level of P the grain yield was statistically same at no lime, 1.25 t/ha and 2.5 t/ha of lime levels but increased significantly at 5.5 t/ha of lime application. This may be due to the fact that at no phosphorus and 45 kg/ha of P_2O_5 levels of P the increase in the levels of lime might have resulted in appreciable increase in the yield due to more availability of phosphorus and other nutrients, but at higher i.e., 90 kg/ha of P_2O_5 level of P the effect of available P due to applied P might have been in confounded with the effect of liming. Similarly, Jackson et al. (1964) reported significant interaction on white clover, red clover and subterranean clover with the application of marked lime and P on the red soil experiment station in Western Oregeon.

Available P was significantly increased due to application of lime, 87 per cent before the crop and 126 per cent after the crop due to 5.5 t/ha over no lime in 0-15 cm depth. In the lower (15-30 cm) depth available P was increased by 25 per cent due to 2.5 t/ha of lime over no lime before the crop and 72 per cent due to 5.5 t/ha of lime application over no lime after the crop. These significant increases in the levels of available phosphorus can be viewed in the light of appreciable (to the extent of one pH unit) rise in pH. At a pH value of about 5.2 or 5.3 phosphorus may exist in Variscite ($Al(OH)_2 H_2PO_4$) or Strengite ($Fe(OH)_2 H_2PO_4$) forms and if pH is raised by about one unit the concentration of these forms present in soil solution as $H_2PO_4^-$ ions may be increased about ten times as indicated by Lindsay and Moreno (1960) in their solubility diagram. This is further supported by Gokhle _et al_. (1954) that liming of lateritic soil from Ratanagiri district increased the efficiency of added soluble P_2O_5. Mariakulandai _et al_. (1955) and Mathan (1964) observed that acid soils of Nilgiris responded to lime by releasing more P_2O_5 which was fixed by the free Fe and Al oxides present in high amounts in these soils. Badanur and Venkata Rao (1975) working with Hebbal red soils reported that liming alone @ 2 t/ha increased the available P content of the soil by 4.9 ppm over initial value of 4.3 ppm. Thus increased availability of soil-P is often cited as one of the principal benefits desired from liming acid soils (Griffin, 1971, and Amrasiri and Olsen, 1973)

The status of available P was also appreciably increased due to application of phosphorus. In 0-15 cm layer available P was increased to 84 and 98 per cent and in 15-30 cm layer 48 and 42 per cent, respectively, before and after the crop due to 90 kg/ha of P_2O_5 over control. This is expected naturally because the phosphorus in superphosphate exist as $H_2PO_4^-$ ion which would result in build up of available P in the soil due to its addition. This is further supported by Albracht and Klemme (1939) that addition of superphosphate to mineral soils approximately doubled the P-content of Lespedza forage over the contained in plants from soil. Bhujbal (1956) and Rai et al. (1963) also reported an increase in the availabla P_2O_5 when superphosphate is applied to the soils.

Generally, interaction between levels of lime and phosphorus was significant in 0-15 cm layer. At the same level of P with increasing level of lime and at the same level of lime with the increasing levels of phosphorus resulted in increase in available P before and after the crop. Practically similar trend of interaction was also noted in 15-30 cm depth. Interactions, in general, indicate the same trend of influence on available P as for different levels of lime and P as explained earlier.

Application of lime resulted in highest per cent (100.1%) increase in Al-P followed by Ca-P (68.5%), organic P (36.2%), Fe-P (39.3%) and the minimum in saloid-P (25.6%)(Table 4). This shows that phosphorus in this soil is fixed in the form of strengite and variscite whose concentrations increases with an increase in pH. Increase in the concentration of Al-P and Fe-P may be explained too in the light of results of Lindsay and Moreno (1960) that solubility of these compounds increases with the increase in pH, hence Al-P and Fe-P increases with lime application. Similar results for Al-P have also been reported by Haynes and Ludecke (1981) in highly leached soils. The Al-P and Fe-P also showed a positive relationship with yield (Table 2). Thus, this behaviour can further be corroborated by the higher solubility of these fractions with increase in pH value towards neutrality might have contributed to available P which ultimately helped in the increase in yield. The lowest increase in saloid-P may be considered due to surface adsorption of this form of phosphorus which, thus, is quite small in its amount and hence least influenced by increase in pH (Table 4). Similar results were obtained by Haynes and Ludecke (1981) that liming addition caused a little change in easily soluble P. The increase in organic-P probably due to the more immobilisation of organic-P because of low mean annual temperature existing in the area. Sood (1983) reported the similar results that immobilisation of organic P was more in these soils.

The highest increase due to application of different levels of P in different forms of this nutrient was noted in organic-P (100.2%) and lowest in Fe-P (17.6%). This behaviour of organic P may be ascribed due to relatively higher amount of organic carbon (average value 1.05%) in the soil. The increase in soil organic P can be explained on the following reasons. Firstly with the addition of lime in the previous crops (one and half year and then again six months back) which resulted in increase in yield. This increased yield might have added organic residues to the soil. During last tw years the organic residue have been decomposed and added the organic matter to the soil ultimately increasing the organic P status of the soil. Secondly the addition of P in all the four crops also resulted in increased yield consequently increasing the organic P of the soil (Badanur and Venkata Rao, 1975). The positive correlation of organic P with yield (Table 2) signifies that some of the organic P might be contributing to the uptake of P. The reason can be that some of the organic P after mineralisation contributing to available P. Sood (1983) in a green house study also reported that organic P do contribute towards availability of P in wheat crop.

The lowest increase in the amount of Fe-P indicates that phosphorus is less fixed, probably due to the lower soluble iron in these soils. Haynes and Ludecke (1981) noted that in such a situation besides the role of calcium in P-fixation the applied P is mainly retained on the thin film of precipitated hydrous oxide of Al and Fe by adsorption with subsequent formation of the respective chemical compounds. This facilitates greater exposure of surface of the retained phosphate resulting in more specific surface activity.

Available N was significantly increased with increase in levels of lime in both the depths before and after the crop (Table 5). Sahu (1965) also reported higher content of available nitrogen in limed plots. This may be due to the increased micro-organisms like ammonifiers (Colzev, 1955) or nitrifiers (Jha, 1965),which ultimately increased the N content of the soil through accelerating the rate of ammonification, atmospheric N-fixation and nitrification processes.

Addition of phosphorus also resulted in increased amount of available N which may be attributed to the increase in the organic matter due to P-addition. Badanur and Venkata Rao (1975) also noted the increase in organic matter content of Hebbal red loamy soils to the extent of 2.14 to 22.80 per cent over control with the addition of phosphorus and lime in combination. Similar results were reported by Anonymous (1980) in a long term experiment being conducted on acid alfisol at Palampur since 1972-73. It was noted that available N increased on an average upto 822.8 kg/ha with NP treatment, during 1972-73 to 1979-80 over initial value of 736 kg/ha.

Application of lime 5.5 t/ha over control resulted in significant decrease (14.9%) in available K at 15-30 cm depth (Table 6). This may be due to the significant reversion of added or exchangeable K to non-exchangeable forms and inhibit the release of exchangeable K, as pointed out by Peech and Bradfield (1943). Pearson (1958) also noted that liming may decrease the rate of release of native soil non-exchangeable K.

In 15-30 cm layer available K was increased significantly by application of 45 kg P_2O_5/ha (9.8%) and 90 kg P_2O_5/ha (6.7%) after the crop. Similar results have been reported by Prasad et al. (1976) in their long term experimentation at acidic red loams at Kanke indicated an increase in exchangeable K-content of the soil due to the application of lime and NPK fertilisers.

Exchangeable Ca^{++} was significantly increased by the increased levels of lime over control both before (62.7%) and after (103.1%) the crop (Table 7 This is naturally expected that applied Ca^{++} in the form of lime would be adsorbed on to the exchange complex with passage of time resulting in increas in exchangeable Ca^{++} , the difference between the amounts before and after the crop can also be attributed to time period . Ca^{++} and Mg^{++} are more energetically bonded to permanent change on soil colloides than to various weakly acid exchange spots, thus availability of Ca^{++} and Mg^{++} increased by liming as reported by Coleman et al. (1959), as more calcium and magnesium move from lime particle to exchange sites as concluded by Sinha and Singh (1966) also.

Available Ca^{++} was increased significantly (19.9%) over control (3.17 me/100g) due to application of 90 kg P_2O_5/ha through single superphospha after the crop. This is naturally expected because of the fact that single superphosphate contains about 17 per cent calcium in the form of monocalcium phosphate and $CaSO_4$ which would result in the increase of exchangeable Ca^{++} due to its addition. Exchangeable Mg^{++} was not affected by the addition of P through single superphosphate over control in the 0-15 cm depth (Table 7).

Interaction between the levels of lime and phosphorus was significant in increasing the exchangeable calcium content. At 45 and 90 kg P_2O_5/ha, amount of exchangeable Ca^{++} was at par due to addition of 1.25 and t/ha dose of lime but it increased significantly with 5.5 t/ha dose of lime t the crop. This may be attributed to formation of di and tri calcium phosphat at lower levels of lime and thus not permitting increase in exchangeable Ca^{+} but due to addition of 5.5 t of lime, part of calcium might have been able t increase the exchangeable Ca status of the soils. At 1.25 t/ha of lime application, both before and after the crop, and at 2.5 t/ha dose of lime after the crop exchangeable Ca^{++} at 45 kg P_2O_5/ha application was at par with no P_2O_5 application. This again may be attributed to the complexing of calcium of lime with the phosphates from the applied superphosphate at the lower level of applied phosphorus. At the higher level of applied P more of Ca of superphosphate itself might have been acted as exchangeable Ca^{++}.

In general, there was appreciable increase in pH even to the extent of 1.2 unit with increased levels of lime both before and after the crop in both the depths (Table 8). This is naturally expected due to the applicatio of lime as there is preponderance of hydroxyl ions due to hydrolysis of $CaCO_3$ in the soil. Several workers have also reported similar increase in pH by liming the acid soils (Alban and Lin, 1958; Barde, 1956; Savant and Kibbe, 1972).

The application of phosphorus has also increased the soil pH to a lesser extent both before and after the crop in both the depths. This may be due to the application of P by single superphosphate as it contain about 17 per cent of the calcium in the form of monocalcium phosphate. The calcium so present might have increased the pH of the soil. Badanur and

Venkata Rao (1975) also showed a slight increase in pH as a result of superphosphate application.

Significant increase in organic carbon content to the extent of 13.2 per cent with the addition of 5.5 t/ha of lime was noted. This increase may be visualised from the point that lime has increased the pH towards neutrality resulting in more availability of many of the plant nutrients thereby increasing the yield (vegetative as well as grain). This increase in yield might have contributed to the addition of plant residues to the soil, which ultimately resulted in increase in the organic carbon of the soil. Badanur and Venkata Rao (1975) also reported an increase of 2.14 to 22.80 per cent over control in organic carbon content with the addition of lime and phosphorus.

Similarly the addition of P has also increased the organic carbon content to the extent of 3.8 per cent. This may be due to the fact that P has increased the yield significantly which has again added the organic residues to the soil. Kanwar and Prihar (1962) reported the beneficial effect of phosphatic fertilisers in increasing the organic carbon content of the soil.

SUMMARY

SUMMARY

Acid soils occupy considerable acreage in Kangra district. These soils have been classified as Alfisols. The soil clays in these soils possess coating of hydroxy Fe and Al, which are known to affect retention and availability of native and added phosphorus. It is because of this high acidity yield per hectare of wheat crop is 12.1 q/ha against 29.0 q/ha of India. In order to improve the productivity of these soils the application of lime is quite often recommended. It is, however, not known, how liming affects the different fractions of inorganic P and as well as organic P fraction. Keeping this in view, a field experiment was conducted at Bhadiarkhar farm of Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, to study the residual effect of lime and direct effect of P on P-fractions, crop yield and soil properties.

The lime treatments comprise of four levels (0, 1.25, 2.5 and 5.5 t/ha) in main plots and phosphorus (0, 45 and 90 kg/ha) in sub-plots. The full dose of lime was applied in the Kharif season of 1982 and one fourth of lime was again applied in the Kharif season of subsequent year. P was applied to the sub-plots in every season along with N and K as a basal dose @ 120 and 60 kg/ha, respectively. The present study was restricted to only Rabi 1983-84 season. The soil samples were collected before and after the Rabi crop along with grain and straw samples after the harvest, from 0-15 and 15-30 cm depths. The important findings of the investigation are summarised below:

1. The average pH values at the start of experiment were 5.1 & 5.3 before the crop and 5.3 & 5.4 after the crop in 0-15 and 15-30 cm depths. It increased to the extent of 1.2 units with increased levels of lime both

before and after the crop in the first layer. But in the second layer, the increase was to a lesser extent (0.6 unit) whereas the applied P did not show any marked change in soil pH.

2. The organic carbon content of the soil was increased significantly with the application of lime and phosphorus. The increase was to the extent of 13.2 per cent after the crop in both the depths whereas the initial organic carbon content was 0.95 per cent. Significant interaction between lime and phosphorus was also observed in case of organic carbon content after the crop.

3. Exchangeable Ca^{++} was significantly increased due to increased levels of lime both before (62.7%) and after (103.1%) the crop. Contrary to this, exchangeable Mg^{++} did not show any significant change by the lime addition. Similar trend was noted with the P application on exchangeable Ca^{++} and Mg^{++} but it was non-significant with exchangeable Ca^{++} before the crop. Interaction effect of lime and phosphorus on exchangeable Ca^{++} was significant both before and after the crop.

4. Available N content of the soil was significantly increased with increase in levels of lime both before and after the crop in both the layers. Due to the application of P the available N increased significantly (9.79%) only before the crop in 0-15 cm depth but decreased significant (8.54%) after the crop in 15-30 cm depth. Lime and phosphorus interaction was also significant in 0-15 cm layer after the crop.

5. Available P content of the soil was significantly increased with addition of lime both before and after the crop in both the depths. This

increase was to the extent of 87.2 and 125.8 per cent in 0-15 cm depth, and 25.4 and 71.6 per cent in 15-30 cm depth before and after the crop, respectively. Applied P also significantly increased the available P content of the soil. Significant interaction between lime and phosphorus on availabl P was found both before and after the crop in both the layers.

6. Lime application resulted in significant decrease in available K content of soil in 15-30 cm depth after the crop only whereas the results were non-significant in upper layer both before and after the crop. P application did not show any significant effect on available K except it increased significantly in the lower depth after the crop.

7. All the P-fractions increased appreciably by the addition of lime. The highest per cent (100.1%) increase in Al-P followed by Ca-P (68.5%), organic P (36.2%), Fe-P (39.3%) and the minimum in saloid-P (25.6%). The highest increase due to application of different levels of P in different forms of phosphorus was noted in organic P (100.2%) and the lowest in Fe-P (17.6%). The effect of P application was more pronounced in organic and total P build up than the lime application.

8. There was a significant positive correlation between grain yield and P-uptake with different P fractions of the soil. These fractions were also related positively with Olsen-P.

9. Grain yield and total P-uptake was increased significantly with the increasing levels of lime. But the lime did not show any significant effect on straw yield. Grain yield, straw and total P uptake was also significantly increased due to the P-application. Interaction effect of lime and phosphorus was also found to be significant with grain yield of the wheat crop

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Original not seen.