QUANTITATIVE EVALUATION O. THE EFFICIENCY OF N AND P SOIL TESTS AND FERTI..IZER RESPONSE TO MAIZE [*Zea mays* L.] THROUGH A MODIFIED MITSCHERLICH -BRAY EQUATION

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH

(AGRICULTURAL UNIVERSITY)
RAHURI DISTRICT -: AHMEDNAGAR
(MAHARASHTRA)

By

SANJEEV SHANKARRAO BABAR
B. Sc. (Agri.) First Class

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (Agriculture)

in

SOIL SCIENCE

DEPARTMENT OF AGRICULTURAL CHEMISTRY & SOIL SCIENCE
Post-Graduate School, Rahuri

March 1980

Dedicated to my

beloved parent

QUANTITATIVE EVALUATION OF THE EFFICIENCY OF N AND P SOIL TESTS AND FERTILIZER RESPONSE TO MAIZE (*Zea mays* L.) THROUGH A MODIFIED MITSCHERLICH-BRAY EQUATION

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Approved by the Advisory Committee :

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Soil Chemist,
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CERTIFICATE

This is to certify that the thesis entitled QUANTITATIVE EVALUATION OF THE EFFICIENCY OF N AND P SOIL TESTS AND FERTILIZER RESPONSE TO MAIZE (Zea mays L.) THROUGH A MODIFIED MITSCHERLICH-BRAY EQUATION, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE embodies the results of a piece of bona fide research work carried out by SHRI. S.S. BABAR under my guidance and supervision and that no part of the thesis has been submitted for any other degree or publication.

Solapur,

Dated : March 4, 82

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Rahuri, 413 722,
Dated : 7/3/80

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Chapter I

I N T R O D U C T I O N

Chapter I

INTRODUCTION

Many concepts/approaches have been employed for evaluation of soil fertility under varied agro-ecological conditions, but a satisfactory method for estimating fertiliser requirements of crops based on soil testing, continues to be a pressing need. Currently, two types of fertiliser recommendations for crop plants are in vogue in the country. One is based on the agronomic experiments without considering soil available nutrients. Obviously, this recommendation is too much generalised.

The second type of semi-quantitative approach is based on arbitrary assumptions and procedures, i.e. categorising soils into low, medium and high or very low, low, moderate, moderately high, high and very high (Bangar and Zende, 1978). It was thought that such groupings or classes may reduce the complexity of making fertiliser recommendation. Similarly, the critical level concept, separates soils with high probabilities of fertiliser response from soils with low probability, but it tells nothing about the exact rate of fertiliser application in relation to varying soil test values of the field.

With the introduction of fertiliser responsive, high yielding crop varieties/hybrids, the role of soil testing, which provides a sound fertiliser recommendation, is more exacting today, than that in the past. An essential requirement for this is the quantification of the relationship between crop yield and yield response on one hand, and supply of plant nutrients from soils and fertiliser sources on the other. In this context, several forms of mathematical and algebric relationships have been employed to express the plant response to nutrient increments.

Amongst them, the modified Mitscherlic-Bray equation is one which has a great diversity in use especially in evaluating the quantitative efficiency of both soil (c_1) and added fertiliser form (c) for formulating the exact fertiliser requirements of crop plants. It was argued by the authors that once the values of 'c_1' and 'c' are established, they are not likely to be changed over a period of time (Biddappa and Patnaik, 1977). It has been further, postulated that the value of c_1 and c can be constant for relatively mobile and immobile soil form of nutrients, when factors like, distribution pattern of the nutrient in the soil relative to plant distribution, form of nutrient, the kind of plant, planting pattern and rate of planting, and climate in promoting plant growth are not varied.

Since, the information on the efficiencies of both soil and added forms of nutrients, particularly for maize is not available, the STCRC investigations were undertaken. It was planned with an idea to find out the correlation of N and P soil tests of vertisols, with maize (Zea mays L.)

hybrid Ganga Safed-2 as an indicator crop through a modified Mitscherlic-Bray equation by laying out field experiments in rainy and winter seasons. The following were the broad objectives of this investigation,

a) to confirm the validity of modified Mitscherlic-Bray equation

b) to derive the c_1 and c constants of the Mitscherlic-Bray equation for the nutrients like N and P

c) to derive and evaluate, polynomial response curves relating to the rates of nutrients like N and P to be applied to maize

d) to work out the N and P fertiliser formulation chart for maize crop, which is based on efficiency factors for soil (c_1) and fertiliser form (c) for both rainy and winter seasons separately.

Chapter II

REVIEW OF LITERATURE

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Chapter II

REVIEW OF LITERATURE

The soil testing has achieved phenomenal success in terms of farmers' acceptance, in few States of India. It is one of the well recognised scientific means for quick characterisation of the fertility status of soils for predicting nutrient requirement of crop plants. In its real prospective, the soil testing tells as to how much and which type of fertiliser should be applied in a particular soil to obtain optimum yield. Besides, there is a real need for obtaining comprehensive and reliable data on the nutrient status of soil. This provides information as to which soil areas are improved and which are in the decline. Trend in the nutrient status would reflect on the effectiveness of research, educational and action programmes. Such a data will also serve as broad basis for estimating fertiliser and lime/gypsum needs for the given areas. Research work carried out on the soil fertility evaluation by employing various concepts/approaches are narrated in the following paragraphs.

2.1. Need for N soil test :

Major portion of N in soil, occures in organic form which is not immediately available to plants. A very small fraction of the total N becomes available to growing crops and its supply depends upon the rate of mineralisation. Meints and Peterson (1973) observed that, the Kjeldahl method of estimating total N was not suitable to measure the indigenously fixed ammonical N which gave nonsignificant correlation with the uptake of hybrid sorghum. Inorganic and organic forms of N are present in soils in different forms like nitrate, ammonium etc. Most of plants take their N in nitrate form.

Deficiency of N deteriorates the quality of crop and reduces the crop yield. Therefore, suitable chemical N tests are needed to diagnose the deficiency or sufficiency of N in soils.

The principle underlying the use of chemical methods excluding organic matter in the determination of total N, is to extract a fraction of the total N which is considered to be proportionately related to the plant available N. These N tests include the measurement of ammonia released by alkaline permanganate, acid and alkali solutions. The amount of amino nitrogen hydrolysed under controlled conditions by alkaline permanganate solution in a given period, is measured as an index of N availability. Bajaj et al. (1967) in Delhi soils, Mehta and Singh (1971) in Gwalior soils, Dubey et al. (1972) and Dangar et al. (1979) in medium and deep vertisols, indicated that the alkaline $KMnO_4$ method of Subbaiah and Asija (1956) proved to be the best for determination of N.

2.2. Need for P soil test :

Plants take up their phosphate principally as $H_2PO_4^-$ and less easily as HPO_4^{--}. These are present in the soil solutions and are derived from (i) adsorbed inorganic phosphates held with iron and aluminium oxides, (ii) humates and clay minerals, (iii) easily acid soluble compounds mainly calcium phosphates and (iv) a small and variable fractions of organic P especially in acid soils. Olsen et al. (1954) developed reliable test for measuring available P in acidic, neutral and alkaline soils. Khera and Datta (1969) used Olsen's method in alluvial soils of Delhi.

Singh and Brar (1973), to correlate different soil tests with maize response for P at different fertility levels of the soil, concluded that Olsen's method was found to be a better index of P availability and correlated well with the yield and P uptake by maize at both the depth of soils (0-15 and 15-30 cm).

Datta and Kamat (1959), Vithal Rao and Kisan Rao (1963), Kumaraswamy et al. (1973), Chandrabhan and Hari Shankar (1973), Cabala Rosand and Santana (1973), Singh and Brar (1973), Shrivastava and Jafri (1974), Bangar (1977) followed Olsen's test to establish the correlation between soil available P and crop response.

2.3. Effects of N and P fertilisation on the yield of maize :

As N and P are required by the plants throughout the entire growth period, the relative efficiency and solubility of nitrogenous and phosphatic fertilizers are very important.

Smith (1952) experienced at Missouri (U.S.A.) that there was an uptake of 167 to 241 kg of N, 50 to 90 kg of P_2O_5 and 101 to 196 kg of K_2O/ha in the maize crop which yielded 62.7 q/ha. Long (1953) at Tennessee valley state (U.S.A.) found that maize crop required 160 kg N, 55 kg P_2O_5, 110 kg K_2O/ha for 100 bushel of crop. Stringfield (1954) stated that the maize crop of 250 bushels/hectare usually removed from each hectare soil 120 kg of N and 62.5 kg of P_2O_5. Grueness *et al.* (1961) observed that N and P uptake were increased with increasing rates of supply of these nutrients at Missouri. Many workers viz. Krantz and Chandler (1954), Thakur *et al.* (1956), Verma and Sharma (1958), Berger (1962), Sharma (1962), Nair (1965) have also reported the different levels of N and P fertilisation for the maize crop.

Singh *et al.* (1965) found that heaviest rate of N of 201.5 kg/ha produced the highest yield of stover and grain of maize. Similar observations were reported by Mandloi (1965), Saxena and Gautam (1966), Schrimpf (1966), Anonymous (1967) and Ghosh (1967).

Sharma and Gupta (1968) at Pantnagar observed that 100 kg N/ha significantly increased the yield of Ganga Safed-2 over 50 kg N/ha and the control.

2.4. Concepts and approaches employed in soil fertility evaluation :

Soil testing can be used in determining the native nutrients of soil and foretelling the fertiliser needs of crops. It is imperative to calibrate the soil tests based on crop performance or yield response to fertilisation. Different groups of scientists employed various approaches, concepts and methodology for soil fertility evaluation under various soil crop environment system, which can broadly be classified as under.

2.4.1. Soil analysis correlation approach :

Bangar and Zende (1978) modified the S.T. rating, and classified the native nutrients of soil (N, P and K) into 6 groups as against 3 groups specified by Muhr et al. (1965).

	Very low	Low	Moderate	Moderately high	High	Very high
Organic carbon (%)	<0.20	0.20-0.40	0.41-0.60	0.61-0.80	0.81-1.00	>1.01
Av.N(kg/ha)	<140	141-280	281-420	421-560	561-700	>701
Av. P_2O_5 (kg/ha)	<15	16-30	31-50	51-65	66-80	>81
Av.K_2O(kg/ha)	<120	121-180	181-240	241-300	301-360	>361

2.4.2. Critical level approach :

Cate and Nelson (1965), pointed out the critical soil test level of nutrient, below which a reasonably satisfactory economic response should be expected from the application of that particular soil nutrient and above which the probability of such response is low. Wagh and Fitts (1966) reported that if soil testing procedure is satisfactory, at least 90 % results should lie in the lower left and upper right quadrants (positive). If most of the plotted data occures in the upper left and lower right quadrants (negative), it indicates that either the extractant is probably not suitable for that particular soil or the experiment is not conducted properly.

2.4.3. Targetted yield :

The idea of targetted yield is originated from Mitscherlich concept. Balasundaram (1979) followed the optimum rate of N with Mitscherlich model for arriving at cost benefit details for the farmer to tailor the yield target. To calculate the amount of nutrients removed by a crop to attain a certain yield level or the amount of fertilizers to be added to meet the requirements of the crop can be determined by the use of Mitscherlich formulae.

2.4.4. Agronomic approach :

All India Co-ordinated Agronomic Research Project of the I.C.A.R. adopted agronomic approach on the fertiliser experiments in the field by different procedures, viz. random selection of fields with due consideration to the agro-climatic conditions and other relevant information. In cultivator's field, experiments are conducted with graded doses of N, P and K fertiliser for recommending proper doses of fertilisers.

2.4.5. Soil fertility-cum-soil survey approach :

On cultivator's fields well defined soil units, such as associations, series and types, help to make the fertiliser recommendation, based on soil fertility and soil survey (Stewart, 1947).

2.4.6. Fertility gradient approach :

The selection of the proper rate of plant nutrients is influenced by a knowledge of nutrient requirement of crop and the nutrient supplying power of the soil on which the crop is to be grown. Fertility gradients are created in as large variation as possible in fertility levels to minimise interference from factors such as environment and management (Ramamoorthy, 1967).

2.4.7. Approach of integrated soil testing :

Colwell (1971) realised that characterisation of available nutrient status by itself, is not sufficient for predicting the responses to added fertilisers, unless one takes into account the other soil variables like bulk density, clay etc.

2.4.8. Probability approach :

Fitts (1955), pointed out that profitable increase in yield can be obtained by plotting fertiliser treatment against soil test values. The index of probability used in percentage yields within a given range of soil tests, may or may not respond to application of soil amendment. The chances of getting response to fertilisers is much greater on soils having low soil test values rather than high.

2.4.9. Soil test calibration by field method :

In southern Brazil, the fast and inexpensive field method was used to calibrate soil testing by using plant height of corn grown under local farm conditions (Martini, 1976).

2.5. Concepts employed in soil and plant studies :

Various concepts have been employed for soil fertility evaluation from time to time which are enumerated as follows.

Bray (1963) expressed that " As the mobility of a nutrient in the soil decreases, the amount of that nutrient needed in the soil to produce a maximum yield (the soil nutrient requirement) increases, and from a variable "net" value, determined principally by the magnitude of the yield and the optimum percentage composition of the crop, to an amount whose value tends to be a constant ".

2.5.1. Liebig's law of minimum :

This concept explained the nature of soil fertility. The law stated that the nutrient present in least relative amount is the limiting nutrient. It implied that all other nutrients were present in excess until the deficient or limiting nutrient was made adequate, whereupon the one present in the next least relative amount became the deficient nutrient and so on (Bray, 1954).

2.5.2. Soil nutrient requirement :

Bray (1945) stated that the supplies of available forms of a nutrient vary from soil to soil, causing a corresponding variation in the fertiliser requirement. These soil supplies can be measured directly with the soil tests. This soil test value can be substituted for 'b' in the modified Mitscherlich equation.

2.5.3. Nutrient mobility concept :

According to Bray (1954) the roots effectively obtain the relatively immobile nutrients like the phosphate forms from the root surface zones.

2.5.4. Percentage sufficiency principle :

In view of limiting nutrient, the amount of nitrogen can be adequate for only one yield while one amount of P or K (immobile nutrients) can be adequate for widely varying yields. Hence, P and K needs are related directly to percentage yield but not to total yield. But more P and K will be needed to maintain the levels in the soil to produce more yields because of the larger amount of the nutrients (Bray, 1958).

2.5.5. Forecast of yield :

The probability of yield is obtained, when all the nutrients are adequate. The kind of plant, the planting pattern and density of plants are determined and also related to the physico-chemical properties of soil and crop season.

2.5.6. Percent yield concept :

Bray (1948) stated that the percent yield was a measure of plant growth than check yield, in soil test correlation, because, even with the equal amounts of applied nutrients, different soils will produce different yield levels on account of the inherent difference in soil fertility. Cate, Hunter and Fitts (1971) calculated the percentage or relative yield by deducting the nutrient being studied from the yield of a complete treatment divided by the yield of a complete treatment, multiplied by 100.

2.5.7. <u>'A' value concept</u> :

Dean and Fried (1952) used the radio-active tracer technique and showed that the original soil content of nutrient 'A' can be obtained from the following relationship.

$$A = \frac{B\,(1-Y)}{Y}$$

Where, B = added amount of labelled fertiliser.

Y = proportion of nutrient in the plant derived from 'B'.

Balba (1971), evaluated the Mitscherlich 'b', Fried and Deans 'A' and Deans' 'a' concept for soil fertility.

2.5.8. <u>Mitscherlich concept</u> :

The ultimate objective in soil fertility studies has been to give sufficient knowledge of soil plant relationship to farmers to enable them to put into practice a balanced fertility programme. It provides an opportunity to the farmer to tailor the yield target in tune with his monetory consideration. Also an attempt was made to work out the optimum rate of N with Mitscherlich model for arriving at cost benefit details.

The general relationship between the supply of a given plant nutrient and the amount of growth, made by the crop was expressed with curvilinear function and logarithmic equation by Mitscherlich (1909). He concluded that the regression coefficient 'c' in the equation is constant for each form of nutrient, regardless of any change in environment. The following mathematical equation was used mainly for analysing the results of fertiliser experiments where the responses to several levels of a given nutrient had been measured. One of the objectives being the calculation of the effectiveness of the nutrient already present in the soil in terms of the fertiliser. A mathematical equation developed by Mitscherlich (1924) is as follows.

$$dy/dx = (A - Y) C$$

Where, dy = increase in yield resulting from an increment of the growth factor.

dx = increment of growth factor in the form of added nutrient (x).

A = maximum possible yield obtained by supplying all growth factors in optimum amount.

Y = yield obtained after application of any given quantity of the factor 'x', and

C = proportionality constant which depends on the nature of growth factor.

2.5.8.1. Utility of Mitscherlich concept :

Murray (1924) stated that the maximum effect of the ingredient applied, is produced and the crop yield will not be further increased by addition of any larger quantity by using Mitscherlich's geometric progression as;

$$dy/dx = K(M-Y) \text{ or } Y = M\,(1-e^{-Kx}).$$

Where, M = maximum obtainable yield by addition of any amount of the source.

Results of cereal yield by application of superphosphate at the rate of 0, 1 and 2 cwt were recorded as 15.25, 28.75 and 37.25 cwt respectively and with the help of these results he worked out the values as M = 51.78, K = 0.4614, X = 0.7556.

Second trial was conducted with 0, 100, 150, 200, 300 and 400 kg/acre of N in the form of Nitrate of soda. The yields recorded were 1610, 2276, 2524, 2730, 3042 and 3250 kg/acre respectively. The values were obtained as ;

$$M = 0.3708, K = 0.382, \frac{k}{100} = 1.49.$$

Bray (1939), Hoover et al. (1942) and Crowther and Yates (1941) had also confirmed the concept of Mitscherlich.

Bray (1944) expressed the equation as log (100-y) = log 100-0.0062.b for the corn crop in colloidal clay (i.e. beidellite-illite type). Wilcox (1955), Reith and Inksen (1963), and Scaife (1968), also successfully utilised the Mitscherlich model for evaluating fertiliser requirement for various crops. Balba (1972) evaluated the corn response to nitrogen by the use of equation, $Y = 0.813\ (1-10^{-0.0845 \times 0.329 - 0.0572\ x})$.

Balasundaram (1979) followed the use of Mitscherlich model for efficient and beneficial cost of fertiliser use for obtaining bumper yield. In sorghum crop, he showed the efficiency factor by the use of equation in sandy-loam and loam soils as -

$$Y = A\ (1-10^{-0.00019.b-0.0046\ x})$$

$$Y = A\ (1-10^{-0.00044.b-0.0046\ x})$$ respectively. The patterns of yield response to fertiliser are complex.

Wilcox (1937) employed Mitscherlich equation, to find out the general and specific quantitative relation between plants, other growth factors and yield. He further stated that the yield of a crop is inversely proportional to its nitrogen content, and is given by the equation $Y = \frac{K}{N}$ where, Y = yield, N = per cent of N in the crop, K = constant.

2.6. Shortcomings of the Mitscherlich equation :

The Mitscherlich equation would desirably be modified in such a way that the effect factor would be determined separately in each test. Bray (1944) using the soil test values for b, found that the Mitscherlich relationship holds good for approximately the same value of 'c_1', although the physical and chemical soil properties might vary within rather wide range and where the ultimate yields under full treatment also vary considerably. Balba and Bray (1956), used b (soil forms), as the soil test value, whereas Mitscherlich used the equation to calculate 'b' in terms of added fertiliser unit. The significance of the "efficiency" factor is discussed and the concept of using these factors to evaluate quantitatively the relative effectiveness of nutrient forms is explained and illustrated.

The validity of fertiliser requirements, predicted on the basis of soil tests, is dependant on calibration of the test values against yield response (Bishop et al. 1967).

2.7. Modification of Mitscherlich concept :

Bray (1929) conducted a field test for available soil P and explained that, ... Neither the attempt has been made to the major composite "availability" of the forms of a given element present nor to a feeding power of the plant roots, simulated in the extracting solution used... Instead of that he took a chemical test on the basis of extract of all the form or forms of elements (Bray, 1948).

Bray (1937) and Cape (1938) followed the modified equation for determination of the nutrient content of a soil. Bray (1944), just modified the equation $dy/dx = (A-Y)C$, as $\log (A-Y) = \log A - c_1 b_1$. On the basis of this equation he expressed that the amount of exchangeable K in the surface soils of the corn belt is directly related to the supply of K to the crop. But the values of c_1 obtained for corn, legumes, soybeans and wheat do not confirm to Mitscherlich's original idea of a constant c_1 values for all crops. On the modified equation, Bray <u>et al</u>. (1945) conducted an experiment on the total organic and available forms of P in soil.

Bray (1945), again modified, and stated that the soil test value can be substituted for b_1 in the equation; $\log (A-Y) = \log A - (c_1 b_1 + c_1 x)$. Because supplies of the available forms of a nutrient vary from soil to soil, causing a corresponding variation in the fertiliser requirement. He calculated $c_1 = 0.0065$, when av. K in the soil ranged from 40-300 lb/acre. It means that the soil requirement of exchangeable K for corn is 300 lb/acre. This is constant for corn within limits, and does not change appreciably for corn belt conditions. Any value of b_1 lower than 300 pounds, therefore, will produce a lower yield, which will be approximately a constant percentage of maximum yield.

Bray (1948), Arnold <u>et al</u>. (1951), Arnold (1953), Bray (1954) also confirmed this concept and expressed that c should vary with a kind of plant, form of nutrient, fertility patterns of the nutrient in the soil, planting pattern and rate of planting. From this analysis, it follows that any variation within these factors will affect the ability of the plant to take up the nutrient and the form of nutrient within the reach of its root system or it will change the value of c.

Baiba et al. (1956) and Bray (1958) expressed the new equation where Bray, recognising the original soil form and added fertilisers, could observe different efficient factors. He modified the original equation -

$$\log (A-Y) = \log A-c (b + x)$$

$$\text{to } \log (A-Y) = \log A-c_1 b_1-cx .$$

The term $c_1 b_1$ is not related to c or x, this is, c_1 and b_1 are independant values rather than being measured in terms of the form of x being given by this equation. The effectiveness of the adsorbed form was found to be 24 times, than the effectiveness of the dilute, acid soluble P in his work.

Findlay (1973), pointed out on Bray's equation, that it is necessary to work on adjacent plots in which level of nutrient is uniform and sufficiently low to permit a relatively large yield response to the nutrient.

2.7.1. Testing of the concept for fertiliser use for various soil/crops :

Bray (1958), expressed the correlation of P soil test with response of wheat (A = 51.6 bushel/acre) for a broadcast and double disced application of soluble phosphate in granada light silt loam soil. The results were obtained in the form of equation :-

$$\log (A-Y) = \log A - 0.0184\ b_1 - 0.25 \log x.$$

Where, b is in lb of sorted P evenly distributed in the surface of 2 million lb of soil as measured by the P test and x is in terms of lb of soluble P_2O_5/acre applied in broadcast and double disced distribution pattern.

Vavra et al. (1959), followed the Mitscherlich-Bray equation, log (A-Y), = log A - 0.0184 b_1 - c for xm. (A = 62.4 bushels/acre). In this, the value of 0.018 for c for yield in the cx form of the equation means, a higher efficiency of the drilled phosphate than a value of 0.25 for c in the c log x form for broadcast phosphate. Like wise, similar observations were obtained by Bray (1963).

Vajragupta et al. (1963), reported that the response to the fertiliser application of P nutrient is usually too small to be measured correctly. Bray P-2 soil test values and rice yield were correlated by the equation :-

$$\log (A-Y) = \log A - 0.158\ b_1 - 0.8 \log x .$$

Mackay et al. (1963 & 1964) and Bishop et al. (1967) followed the Bray equations relating potato yield to soil nitrate production and N fertiliser, exchangeable K and K fertiliser, and av.P and phosphate requirements, respectively, in fresh sample and air dried sample for vally and mountain soil groups as under,

Soil group	Efficiency factor	Nitrate	Av. soil P (Olsen soil test)
Vally	c_1	0.0242	0.0186
Mountain	c_1	0.0131	0.0210
Vally	c	0.0052	0.0033
Mountain	c	0.0052	0.0039

Balasundaram et al. (1972) using the equation [$\log (A-Y) = \log A - 0.0059\ b - 0.0115\ x$] for CSH-1 in the calcareous soil calculated the efficiency factors for soil and fertiliser. Dhanapalan et al. (1973) following the equation [$\log (A-Y) = \log A - 0.0018\ b_1 - 0.0067\ x$] in Kalathur series for high yielding rice varieties tested in the trials, correlated the soil nitrogen with N response.

Balasundaram (1975) stated the economic dose on ragi by Bray equation. The economic dose was found to be 58.6 kg of N/ha, 20.0 kg P/ha and 13.6 kg of K/ha in black soils. Similarly, Balasundaram et al. (1976) worked out the economic fertiliser formulations by Bray's equation for rice.

Sarkar (1977) calculated the P fertiliser requirement of sugar-beet by Bray equation [log (100-Y) = log 100-0.018 b_1 - 0.0084 x] with Olsen soil P test values for the economic yield under Turkish soil and cultural conditions.

Biddappa and Patnaik (1977) conducted field experiments on the effects of increasing rate of N and P on yield response of rice. Efficiency factors for native and added fertilisers have been calculated on the basis of Mitscherlich-Bray equation. Evaluation of site specific recommendation based on these efficiency factors, as 86.2 kg of N and 14.4 kg of P_2O_5/ha was considered optimum for obtaining 87.5 per cent of theoretical maximum yield (3236 kg/ha) in kharif and 111.0 kg N and 20.8 kg P_2O_5/ha for getting 87.5 per cent of theoretical maximum yield (4375 kg/ha) in rabi season, respectively.

Chapter III

MATERIALS AND METHODS

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Chapter III

MATERIALS AND METHODS

The present investigation on soil test crop response correlation was undertaken in rainy (Kharif) and winter (Rabi) seasons of 1978-79 with a view to find out the correlation of N and P soil tests with maize (*Zea mays* L.) hybrid Ganga Safed-2 as an indicator crop through a modified Mitscherlich-Bray equation, by laying out field experiments on the vertisols of Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722.

3. Materials :

3.1. Soils :

The experiments were laid out on a medium black soil of Sawargaon series of vertisols. Sawargaon series comprise the members of fine montmorillonitic, isohyperthermic family of *Vertic ustropepts*. It contains few lime concretions at the surface and the substrata possessed yellowish brown to brownish gray colour. The effective rooting depth on an average is moderately deep, extending from the depth of 45 cm to the surface. Generally, these soils are cultivated for maize, sorghum, wheat, vegetables and several horticultural crops.

3.2. Soil sampling technique :

For examining the physico-chemical properties of the soils, representative soil samples were collected by Hoffer's tube from a genetic layer of 0-15 cm of each plot in both rainy and winter seasons. The soil samples were kept in butter paper bags and then transported to the laboratory for further processing. They were dried in shade on clean white papers and crushed in a wooden morter and pestle to pass through a 2 mm sieve, and stored in properly labelled cartoon boxes for further chemical analysis.

3.2.1. Physico-chemical properties of the soil :

The physico-chemical characteristics of the soils are presented in Table 1.

Table 1 : Physico-chemical properties of the soils (Average of 15 soil samples).

Properties	Sample I Rainy season	Sample II Winter season
Sand %	24.00	21.15
Silt %	21.80	21.42
Clay %	48.10	51.26
pH	8.05	8.00
Conductivity (mmhos/cm^2)	0.31	0.33
Free lime ($CaCO_3$ %)	7.85	8.43
C.E.C. (meq /100 g soil)	57.40	53.12
Organic carbon %	0.44	0.41
Available N (kg/ha)	185.10	192.00
Available P (kg/ha)	8.25	8.80
Available K (kg/ha)	527.05	507.96

The soils are medium black in colour derived from Deccan trap. It is alkaline in reaction having a few lime concretions in the clay matrix. The fertility status is low for available N and P and higher for available K.

3.3. Experimental details :

Nitrogen and phosphorus series experiments were conducted in rainy and winter seasons in 1978-79 separately. The details of the layout of the experiments conducted are dpicted in Fig. 1 and 2 respectively.

The experimental details are as under -

	Rainy	Winter
Design	R.B.D.	R.B.D.
Replications	3	3
Number of treatments		
i) N series	9 levels	9 levels
ii) P series	6 levels	6 levels
Gross plot size (m)	6.3 x 3.0	6.3 x 3.0
Net plot size (m)	3.0 x 1.8	3.0 x 1.8
Spacing (cm)	30 x 60	30 x 60
Sowing date	12 July 1978	22 Oct 1978
Harvesting date	24 Oct 1978	8 Feb 1979
Plant density (plants/ha)	55,555	55,555

Thining and gap filling were performed eight days after sowing and only one healthy plant was retained at each hill. Weeding was done after one month of sowing.

RAINY SEASON 1978-79

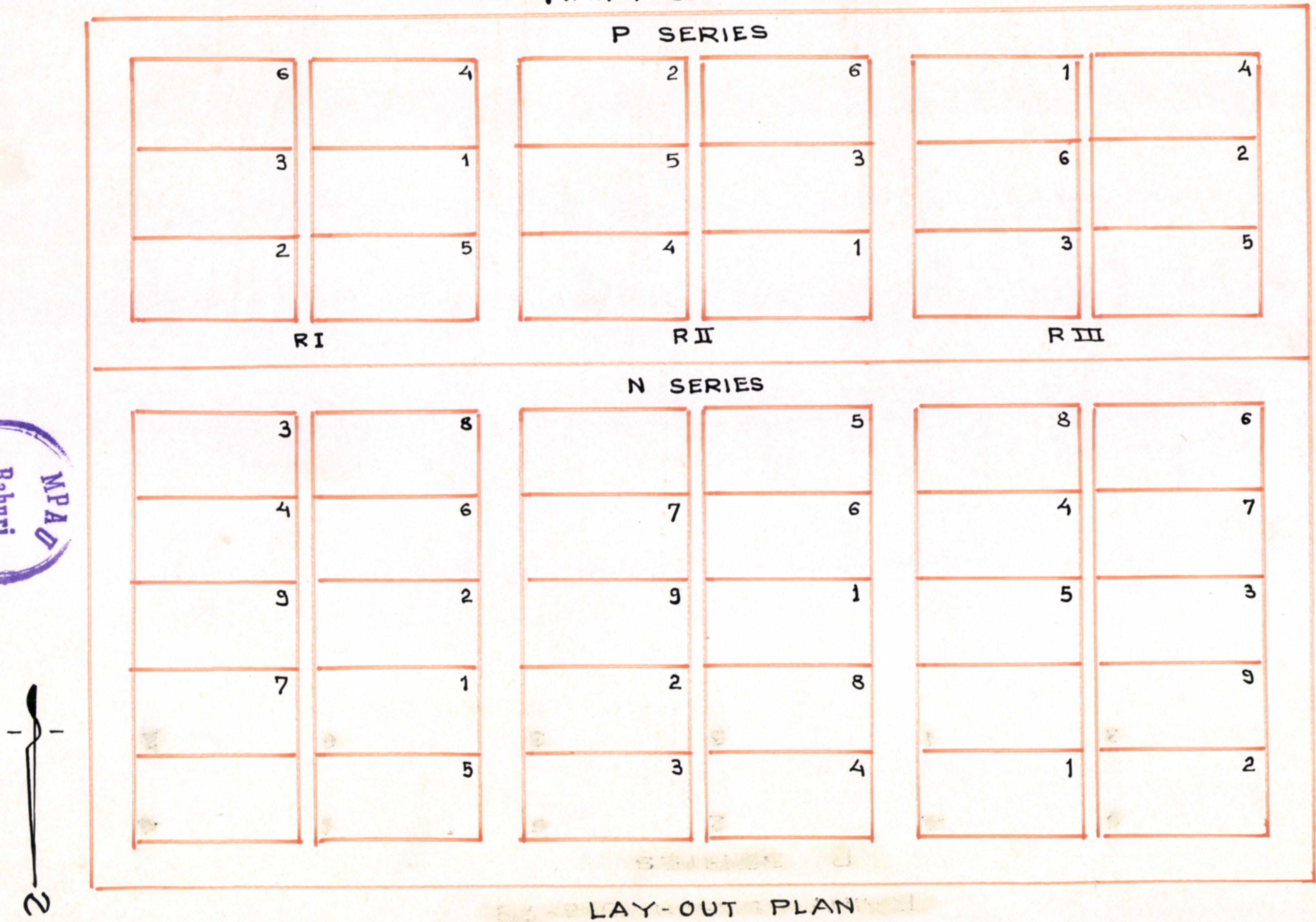
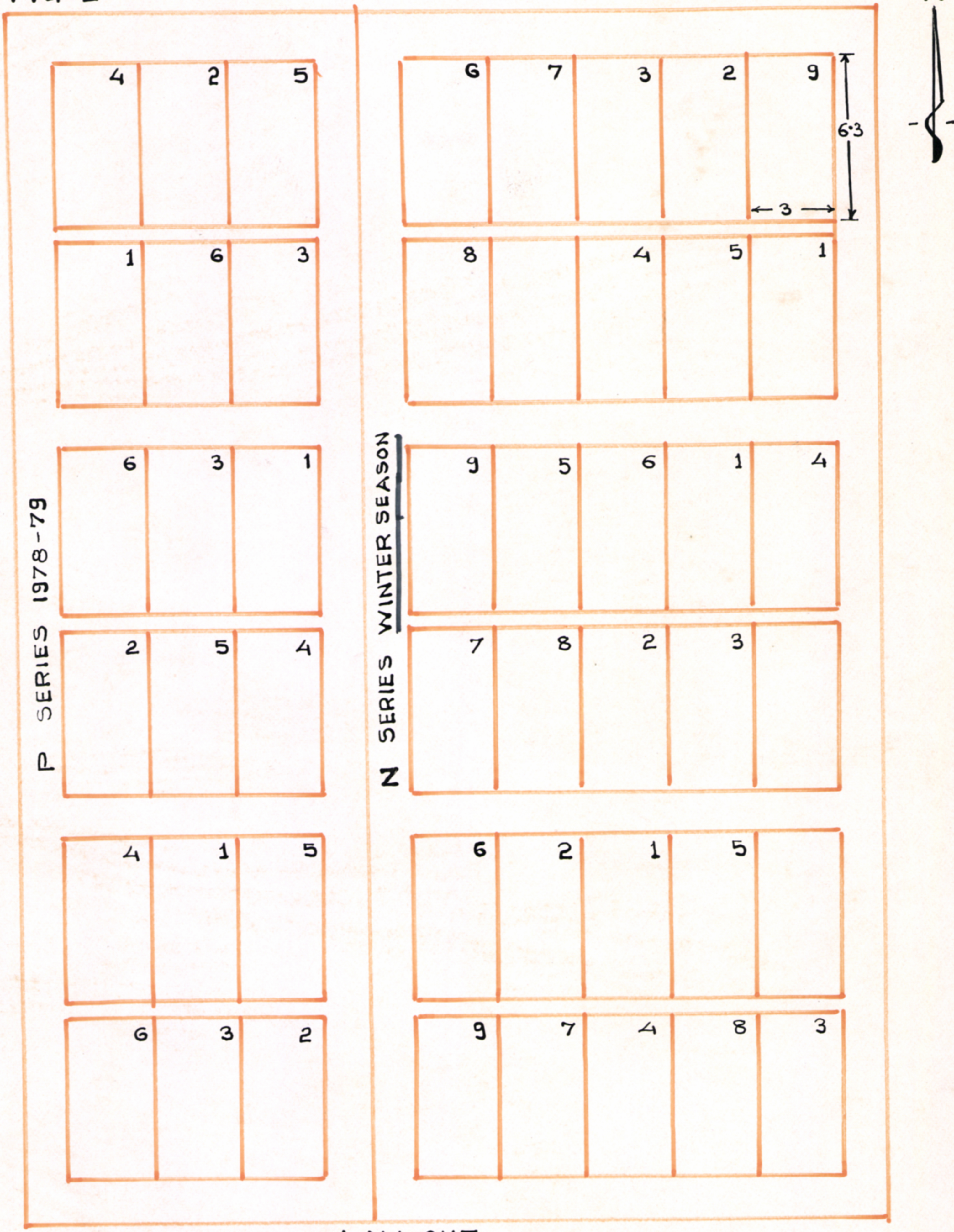


FIG. 1

LAY-OUT PLAN

FIG. 2



LAY-OUT
PLAN

3.4. Details of treatments :

N. Series :

Treat. No.	Treatments	N(kg/ha)	N (kg/plot)
1.	$N_0P_1K_1$	0	0.000
2.	$N_1P_1K_1$	25	0.105
3.	$N_2P_1K_1$	50	0.210
4.	$N_3P_1K_1$	75	0.312
5.	$N_4P_1K_1$	100	0.420
6.	$N_5P_1K_1$	125	0.526
7.	$N_6P_1K_1$	150	0.632
8.	$N_7P_1K_1$	175	0.736
9.	$N_8P_1K_1$	200	0.842

For N series, half of the dose of N was applied immediately after sowing and rest half of the dose was given after one month in all the treatments. Basal dose of P_2O_5 at the rate of 75 kg/ha and K_2O 60 kg/ha were added in each of the treatments for achieving sufficiency level of soil fertility.

P. Series :

Treat.No.	Treatments	P_2O_5(kg/ha)	P_2O_5(kg/plot)
1.	$P_0N_1K_1$	0	0.000
2.	$P_1N_1K_1$	20	0.241
3.	$P_2N_1K_1$	40	0.482
4.	$P_3N_1K_1$	60	0.723
5.	$P_4N_1K_1$	80	0.964
6.	$P_5N_1K_1$	100	1.105

For the P series, half of the dose of N was applied immediately after sowing and rest half of the dose was given after one month in all the treatments. The N at the rate of 125 kg/ha and K_2O at the rate of 75 kg/ha as basal doses were applied for obtaining sufficiency level of soil fertility.

The N, P and K were applied to the soil at the time of sowing through urea (44.83 % N); single superphosphate (15.65 % P_2O_5), and muriate of potash (60 % K_2O) respectively.

3.5. Irrigation :

The first light irrigation was given on the day of sowing as there was a moisture deficit in the soil. Thereafter, the irrigation interval of 12 days was maintained throughout the life span of the crops. In all six irrigations for rainy season and 9 irrigations during winter season were given.

3.6. Plant protection umbrelas :

For protecting the crop from stalk-borer infestation during seedling stage, spraying the Endrin 20 EC at the rate of 700 ml in 70 litres of water per hectare was adopted and the same was repeated after a fortnight.

3.7. Determination of plant element :

For determining the mineral constitution (N, P and K) of the maize crop, two plant samples were collected from each of the treatments of 3 replications from N and P series at knee high, tasseling and harvest stages. The plant samples were cut off close to the ground by knife and packed in a brown paper bags. At harvest stage, the grain and stover samples were collected separately. They were dried in the shade and subsequently in the oven at constant temperature of 65°C. Further, they were milled properly through a willey mill (20 mesh sieve) and preserved in small brown bags for determinations of mineral make up with regard to N, P and K.

Methods of analysis :

3.8. Soil :

The soil samples were chemically processed as per the methods shown in Table 2.

Table 2 : Analytical methods for soil analysis.

Characteristics	Method adopted	Reference
1. Soil reaction	1:2.5(soil to water ratio)	Bates, 1954
2. Electrical conductivity	Conductometric (1:2.5 (soil to water ratio)	Jackson, 1958
3. Mechanical analysis	International Pipette	Piper, 1966
4. Free lime ($CaCO_3$)	Calcimeter	Allison and Moodie, 1965
5. C.E.C.	Ammonium acetate	Bremner and Keeney, 1965
6. Organic carbon	Rapid titration	Walkley and Black, 1934
7. Total nitrogen	With Bal's modification	Jackson, 1967
8. Available nitrogen	Alkaline permanganate	Subbiah and Asija, 1956
9. Available phosphorus	0.5 M $NaHCO_3$ (pH 8.5)	Olsen et al., 1954
10. Available potassium	Neutral Normal ammonium acetate	Hanway and Heidel, 1952.

3.9. Plant :

The plant samples were digested by using 30 % H_2O_2 and concentration H_2SO_4 in 1:1 proportion (Parkinson and Allen, 1975). The plant samples were chemically processed as per the methods shown in Table 3.

Table 3 : Analytical methods for plant analysis.

Characteristics		Method adopted	Reference
1.	N	Micro-kjeldahl	Black, 1965
2.	P	Vanadomolybdophosphoric acid yellow colour	Black, 1965
3.	K	Lange's flame photometer	Black, 1965

3.9. Statistical analysis :

3.9.1. Data collected were computed by using statistical methods for agricultural worker as described by Panse and Sukhatme (1957).

3.10. Logarithmic equations :

Theoretical maximum yield (Y axis intercept of the curve log Y against 1/x).

$$\Sigma Yi = \text{No. of treatments (c)} + \Sigma Xib. \quad \ldots \quad 3.1$$

$$\Sigma XiYi = \Sigma X\,(c) + \Sigma X^2 b \quad \ldots \quad 3.2$$

Where, log c = Theoretical maximum yield, and for further calculation of different doses of fertilisers.

$$\log y = c - \frac{b}{X} \qquad \ldots \quad 3.3$$

Where, X is the dose of fertiliser.

<u>Fitting the curvilinear production function equation</u> :

$$Y = a + bx + c\,x^2 \qquad \ldots \quad 3.4$$

Correlation coefficient (Y) and coefficient determinations ... 3.5

<u>Evaluation of constants 'c_1' and 'c' as per Mitscherlich-Bray equation</u> :

$$\log (A-Y) = \log A - c_1 b - cx \qquad \ldots \quad 3.6$$

Where, A = Theoretical maximum yield.

b = Native soil nutrient.

c_1 = Efficiency factor for soil.

c = Efficiency factor for added nutrient.

x = Added nutrient.

<u>Efficiency factor for soil (c_1)</u> :

$$c_1 = \frac{\log A - \log (A-Yo)}{b} \qquad \ldots \quad 3.7$$

Where, A = Maximum obtainable yield.

$$Yo = \frac{\text{Control yield x 100}}{\text{Theoretical maximum yield}} \qquad \ldots \quad 3.8$$

i.e. control yield expressed as % of theoretical maximum yield 'A'.

b = Soil test value of nutrient expressed in kg/ha.

<u>Efficiency factor for added nutrient (c)</u> :

$$c = \frac{(\log A - c_1 b) - \log (A-Yx)}{x} \qquad \ldots \quad 3.9$$

Where, x = added fertiliser nutrient.

Yx = Yield at x level of fertiliser nutrient added.

Equation 3.9 becomes

$$c\,x = \log A - c_1 b - \log (A - Yx) \qquad \ldots \quad 3.10$$

On the basis of equation 3.10

$$c = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{N}}{\sum X^2 - \frac{(\sum X)^2}{N}} \qquad \ldots \quad 3.11$$

<u>The site specific recommendation of fertiliser for maize through Baule Unit</u> :

a) Baule equivalent to soil/fertiliser nutrients, M

$$M = \frac{0.301}{\text{efficiency factor for } c_1 \text{ or } c} \qquad \ldots \quad 3.12$$

Baule equivalent, M adopting efficiency factors, c_1 or c are used for soil or fertiliser nutrients respectively.

b) Baule units for soil nutrient, N

$$N = \frac{b}{M \text{ for soil}} \qquad \ldots \quad 3.13$$

c) Fertiliser recommendation for yield.

$$\text{kg/ha of fertiliser} = \left(\text{No. of Baule units required as 0, 1, 2, 3 or 4} - \text{Baule units of soil nutrients}\right) \times \text{Baule equivalent of fertiliser nutrients.} \qquad \ldots \quad 3.14$$

Chapter IV

RESULTS AND DISCUSSION

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Chapter IV

RESULTS AND DISCUSSION

For monitoring the effect of graded levels of N and P on the yield and uptake of N and P by maize, two field experiments were conducted one each in rainy (*kharif*) and winter (*rabi*) seasons on N and P series on the Savargaon series of vertisols. Further, by mathematical manipulation, the quantitative evaluation of the efficiency of N and P soil tests and fertiliser response to maize through a modified Mitscherlich-Bray equation were worked out with a view to find out the fertility constants in regards to N and P. The results of the experimentation are discussed below.

4.1. N series :

4.1.1. Effect of graded levels of N on the dry matter productions at different stages :

Effect of different N treatment on the dry matter production at knee high, tasseling and harvest (grain and stover) stages of maize in rainy and winter seasons were statistically tested and data are presented in Table 4 and also graphically depicted in Fig. 3.

4.1.1.1. Dry matter production in rainy season :

The data in Table 4 revealed that the treatment differences of N on the dry matter production at knee high and tasseling stages were found to be significant.

The highest dry matter production of 38.52 g/plant at knee high and 148.85 g/plant at tasseling stages were recorded by the application of 200 kg N/ha. However, there were no significant differences in the yield due to the application of N at the rate of 125, 150, 175 and 200 kg/ha at knee high stage. Similarly, the DM production due to the application of N at the rate of 175 and 200 kg/ha at tasseling stage was on par. Significantly lowest DM yield was observed in check plots. Almost similar observation was also reported by Bhosale (1968) for Deccan Double hybrid maize. The DM productions due to the application of N at all the levels, significantly increased the yields of maize as compared to the control ($N_0P_1K_1$), except the treatment $N_1P_1K_1$ at knee high stage.

The effect of different N levels on the grain and stover productions (Table 4) at harvest stage indicated that significantly highest grain production (72.15 q/ha) was observed in the treatment 200 kg N/ha. However, there were no significant differences in the treatments, where N were applied at the rate of 125, 150, 175 and 200 kg/ha. The application of N at the rate of 50 kg/ha and its all the higher levels were significantly superior in increasing grain yield of corn as compared to $N_0P_1K_1$ and $N_1P_1K_1$ treatments, but these treatments on par with each other.

Similar trend due to the effect of graded levels of N on the stover productions was also observed as seen in grain production. These results are in confirmity to those reported

Table 4 : Effect of graded levels of N on the dry matter yield of maize at different stages of crop growth.

Treatment	Rainy season				Winter season			
	Dry matter				Dry matter			
	Knee high	Tasseling	Harvest		Knee high	Tasseling	Harvest	
			Grain	Stover			Grain	Stover
	g/plant		q/ha		g/plant		q/ha	
$N_0P_1K_1$	15.93	52.14	24.94	29.90	12.40	43.34	20.273	23.790
$N_1P_1K_1$	23.41	71.82	28.22	38.33	17.53	55.75	26.610	32.198
$N_2P_1K_1$	27.62	98.03	35.91	43.69	20.45	68.18	31.323	35.877
$N_3P_1K_1$	29.22	115.98	46.47	56.71	23.71	85.45	35.393	37.315
$N_4P_1K_1$	27.69	123.58	52.70	64.17	24.35	97.06	39.553	45.043
$N_5P_1K_1$	32.16	130.25	64.56	78.73	26.06	107.76	44.783	51.997
$N_6P_1K_1$	35.44	136.26	68.71	81.43	28.12	116.50	47.725	56.316
$N_7P_1K_1$	38.00	143.17	70.97	86.92	31.33	121.00	50.120	59.143
$N_8P_1K_1$	38.52	148.85	72.75	88.01	30.55	123.17	52.440	63.617
F test	*	**	**	**	**	**	**	**
S.E. ±	2.82	2.06	2.945	3.529	0.6827	1.782	0.781	1.393
C.D. at 5 %	8.44	6.18	8.829	10.158	2.1512	5.341	2.340	4.176
1 %	11.91	8.71	12.1251	14.530	3.0598	7.533	3.302	5.889

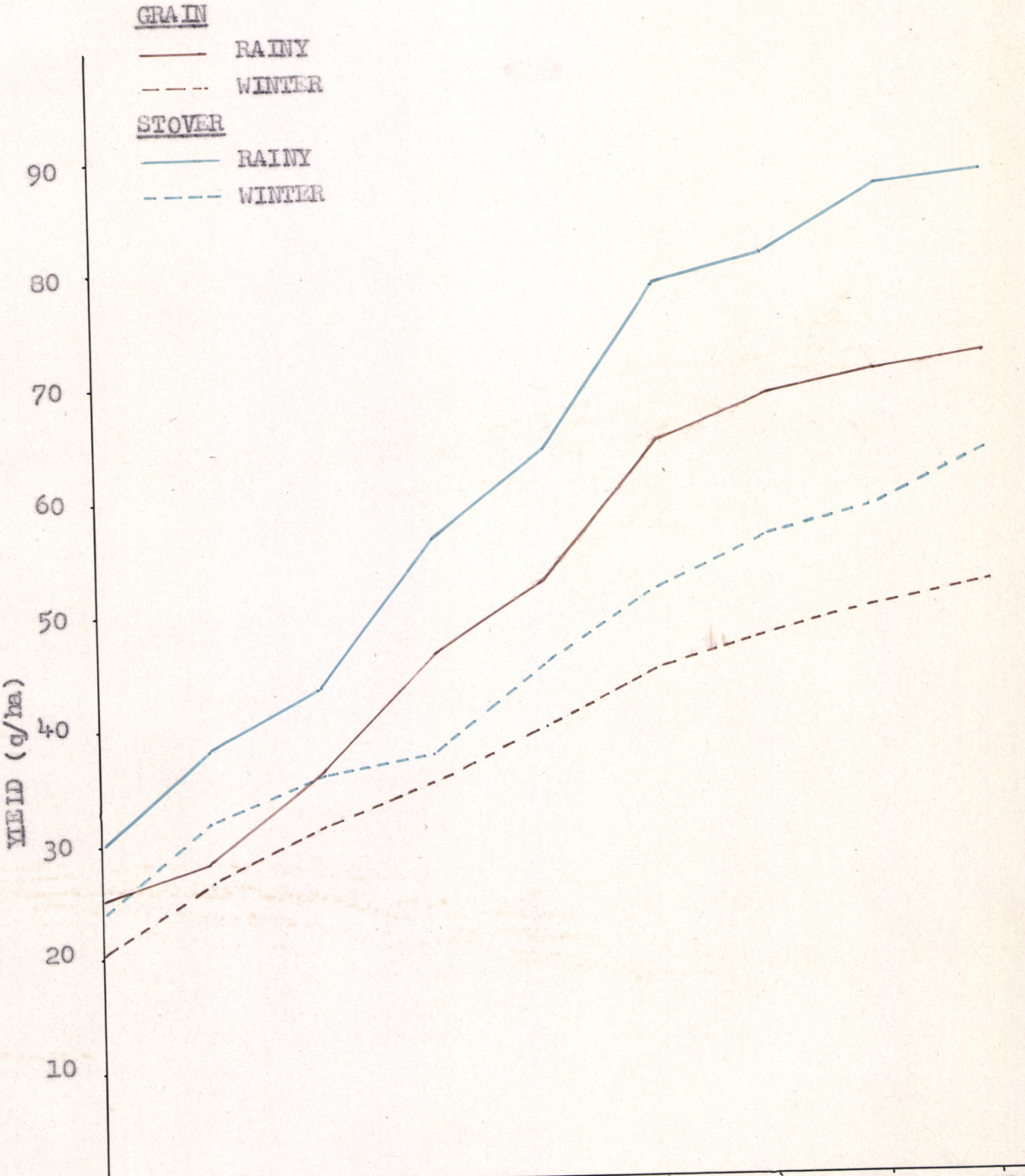

FIG. 3 : EFFECT OF GRADED LEVELS OF N ON THE GRAIN AND STOVER YIELD OF MAIZE AT DIFFERENT SEASONS.

by Singh *et al.* (1965), Anonymous (1967) and Lasztity (1974) in calcareous sandy soils with maize as an indicator crop.

4.1.1.2. DM production in winter season

An appraisal of Table 4 revealed that the addition of N at all the levels significantly increased the DM yield of maize at knee-high and tasseling stages as compared to no nitrogen. Significant higher DM production at knee-high and tasseling stages were observed in the treatment 175 and 200 kg N/ha respectively as compared to the rest of the treatments. However, these treatments were on par with each other. The DM productions in the treatments 125 and 150 kg N/ha were found to be on par with each other at knee high stage.

The N fertilization at all the levels significantly increased the grain and DM yields of maize as compared to no nitrogen. Significantly highest grain production (Table 4) was observed by the N application at the rate of 200 kg/ha. The application of N at the rate of 175 kg/ha was on par with 200 kg of N/ha in both grain and DM production.

Similar observations were also perceived by Phadke (1970), Mandloi *et al.* (1971) and Singh and Brar (1973).

Comparison of DM production in rainy and winter seasons revealed that grain and stover productions in rainy season was comparatively more than in the winter, indicating the superiority of the former over the later. It may presumably be due to the optimum soil temperature, seasonal effect which has initiated in the better root growth and ultimately resulted into higher DM production.

4.1.2. Concentration and uptake of N as influenced by the graded levels of N at various stages of corn :

The data of the per cent concentration and uptake of N, P and K at different stages were processed statistically and are presented in Tables 5, 6, 7, 8, 9, 10, 11 and 12 for rainy and winter seasons.

4.1.2.1. Rainy season :

Perusal of the Table 5 and 6 revealed that the N concentrations were increased with the corresponding increase in N levels upto certain extent ($N_6P_1K_1$), but it was declined later on ($N_7P_1K_1$ and $N_8P_1K_1$) at knee high and tasseling stages as per the law of diminishing returns. Significantly, the highest concentration of N (1.160 %) at knee high and (0.740 %) at tasseling stage were found in the treatments 150 kg of N/ha. However, the application of 150 kg N/ha was on par with the treatments where N was applied at 200, 175 and 100 kg/ha at knee high stage. At tasseling stage, all the treatments were on par with each other except control ($N_0P_1K_1$). Similar observation was also reported by Shinde (1972). As regards, the uptake of N at both stages, it was found to be significant. The application of N at the rate of 125 kg/ha was on par with 150, 175 and 200 kg/ha of N at knee high stage when the uptake of N was considered. The uptake of N in the treatments 175 and 200 kg N/ha was found to be on par with each other at tasseling stage.

Table 5 : % concentration of N, P and K in the maize plants at different stages of growth, as affected by levels of N (Rainy season).

Treatment	Knee high			Tasseling		
	N	P	K	N	P	K
$N_0P_1K_1$	0.990	0.303	1.710	0.703	0.230	1.52
$N_1P_1K_1$	1.003	0.344	1.693	0.713	0.246	1.52
$N_2P_1K_1$	1.013	0.382	1.687	0.726	0.243	1.53
$N_3P_1K_1$	1.020	0.415	1.657	0.727	0.250	1.52
$N_4P_1K_1$	1.110	0.417	1.633	0.736	0.250	1.53
$N_5P_1K_1$	1.136	0.413	1.543	0.733	0.253	1.55
$N_6P_1K_1$	1.160	0.387	1.407	0.740	0.243	1.53
$N_7P_1K_1$	1.130	0.351	1.373	0.737	0.243	1.52
$N_8P_1K_1$	1.130	0.331	1.250	0.735	0.233	1.51
F test	**	**	N.S.	*	N.S.	N.S.
S.E. ±	0.033	0.0025	0.026	0.0078	0.0048	0.0185
C.D. at						
5 %	0.099	0.0074	-	0.0233	-	-
1 %	0.139	0.0106	-	0.0329	-	-

Table 6 : Uptake of N, P and K (g/plant) by maize plant at different stages of growth, as affected by levels of N (Rainy season).

Treatment	Knee high			Tasseling		
	N	P	K	N	P	K
$N_0P_1K_1$	0.160	0.048	0.273	0.37	0.122	0.79
$N_1P_1K_1$	0.240	0.082	0.397	0.51	0.178	1.09
$N_2P_1K_1$	0.283	0.105	0.466	0.71	0.239	1.50
$N_3P_1K_1$	0.300	0.121	0.480	0.85	0.290	1.76
$N_4P_1K_1$	0.310	0.116	0.451	0.91	0.309	1.89
$N_5P_1K_1$	0.365	0.133	0.497	0.96	0.330	2.02
$N_6P_1K_1$	0.411	0.138	0.497	1.01	0.332	2.08
$N_7P_1K_1$	0.429	0.134	0.522	1.055	0.348	2.17
$N_8P_1K_1$	0.435	0.128	0.481	1.096	0.347	2.25
F test	*	**	**	**	**	**
S.E. ±	0.04	0.0047	0.0003	0.021	0.00612	0.0184
C.D.at 5 %	0.1199	0.014	0.00097	0.064	0.0184	0.055
1 %	0.1692	0.020	0.0014	0.090	0.0259	0.078

At knee high stage, the concentration and uptake of P were found to be significant, while the concentration of K was observed to be non significant, but the uptake of K found to be significant. The concentration of P and K were found to be non significant, but uptake of P and K found to be significant at tasseling stage.

Table 7 : % concentration of N, P and K in the maize plants at harvest stage as affected by levels of N (Rainy season).

Treatment	Grain			Stover		
	N	P	K	N	P	K
$N_0P_1K_1$	1.243	0.303	0.427	0.293	0.122	1.58
$N_1P_1K_1$	1.300	0.307	0.420	0.294	0.126	1.63
$N_2P_1K_1$	1.396	0.312	0.415	0.297	0.129	1.656
$N_3P_1K_1$	1.467	0.317	0.413	0.300	0.130	1.693
$N_4P_1K_1$	1.533	0.333	0.403	0.310	0.135	1.740
$N_5P_1K_1$	1.600	0.337	0.393	0.323	0.139	1.806
$N_6P_1K_1$	1.684	0.327	0.390	0.336	0.135	1.870
$N_7P_1K_1$	1.667	0.293	0.380	0.350	0.133	1.857
$N_8P_1K_1$	1.653	0.283	0.360	0.390	0.131	1.817
F test	**	N.S.	N.S.	*	*	**
S.E. ±	0.45	0.0205	0.0236	0.0165	0.228	0.0246
C.D. at 5 %	0.135	-	-	0.0493	0.689	0.072
1 %	0.190	-	-	0.0693	0.973	0.105

The data in Table 7 and 8 at harvest stage indicated that the significantly highest concentration of N (1.684 %) in grain and (0.390 %) stover were observed in the treatments 150 kg N/ha ($N_6P_1K_1$) and 200 kg N/ha ($N_8P_1K_1$), respectively. The application of N at the rate of 125, 150, 175 and 200 kg/ha were on par with each other when the concentration of N in grain was considered. The treatments of 175 and 200 kg of N/ha in stover yield were observed to be similar. The application of N at 50 kg/ha and its all the higher levels were significantly superior in increasing concentration of N in grain as compared to $N_0P_1K_1$ and $N_1P_1K_1$.

Table 8 : Uptake of N, P and K (kg/ha) by maize crop at harvest stage, as affected by levels of N (Rainy season).

Treatment	Grain			Stover		
	N	P	K	N	P	K
$N_0P_1K_1$	30.493	7.440	10.458	8.739	3.649	47.167
$N_1P_1K_1$	36.852	8.655	11.845	11.211	4.819	62.551
$N_2P_1K_1$	50.140	11.194	15.109	12.956	5.632	72.458
$N_3P_1K_1$	67.903	14.643	19.100	16.974	7.380	96.158
$N_4P_1K_1$	80.400	17.200	20.956	19.852	8.638	111.818
$N_5P_1K_1$	102.640	21.611	26.365	25.637	10.943	142.940
$N_6P_1K_1$	112.817	22.380	26.714	27.463	10.971	152.320
$N_7P_1K_1$	118.170	20.723	26.837	30.406	11.532	161.370
$N_8P_1K_1$	122.782	20.191	25.758	34.197	11.540	159.730
F test	**	**	**	**	**	**
S.E. ±	3.095	0.693	0.771	1.324	0.491	7.094
C.D. at 5 %	9.270	2.078	2.312	3.969	1.472	21.148
1 %	13.110	2.930	3.384	5.499	2.115	30.033

Further, it was observed that the concentration of P and K in grains as affected by the application of different

N levels was found to be non significant. But, when total uptake was considered, it was found that N fertilization significantly influenced the uptake of P and K. This may be due to increased DM production by the N application which resulted into increase in uptake of P and K by the crop.

These results are in close confirmity as reported by Chaugule (1968), Moreover, Kharche (1969) reported that the N content of maize grain showed a positive increase with increasing level of N.

4.1.2.2. Winter season :

The concentration and uptake of N, P and K as affected by graded levels of N at knee high and tasseling stages were statistically analysed and are presented in Tables 9 and 10.

An appraisal of Tables 9 and 10 revealed that the treatment differences on the concentration and uptake of N were found to be significant. Significantly, highest concentration of N (1.15 %) in maize plant was recorded at 150 kg N/ha followed by 200, 175 and 100 kg N/ha at knee high stage. However, there was no significant differences among these treatments. Significantly, highest concentration of N (0.747 %) was found to be in the treatment 150 kg N/ha followed by rest of treatments at tasseling stage.

Significantly, lowest concentration and uptake of N was found in check plots at knee high and tasseling stage.

Table 9 : % concentration of N, P and K in the maize plants at different stages of growth, as affected by levels of N (Winter season).

Treatment	Knee high			Tasseling		
	N	P	K	N	P	K
$N_0P_1K_1$	0.99	0.312	1.717	0.680	0.207	1.547
$N_1P_1K_1$	1.00	0.357	1.703	0.706	0.207	1.550
$N_2P_1K_1$	1.01	0.399	1.660	0.710	0.207	1.547
$N_3P_1K_1$	1.02	0.425	1.630	0.713	0.203	1.557
$N_4P_1K_1$	1.10	0.429	1.553	0.723	0.203	1.560
$N_5P_1K_1$	1.15	0.417	1.547	0.733	0.207	1.550
$N_6P_1K_1$	1.15	0.391	1.410	0.747	0.190	1.533
$N_7P_1K_1$	1.13	0.367	1.363	0.743	0.187	1.540
$N_8P_1K_1$	1.14	0.348	1.260	0.740	0.177	1.530
F test	*	**	**	*	N.S.	N.S.
S.E. ±	0.025	0.004	0.024	0.018	0.006	0.010
C.D. at 5 %	0.075	0.012	0.072	0.054	-	-
1 %	0.106	0.016	0.102	0.076	-	-

The concentration in the maize plants of P and K (Table 9) as influenced by N application were found to be significant at knee high, but, at tasseling stage, it was found to be not significant.

Table 10 : Uptake of N, P and K (g/plant) by maize plant at different stages of growth, as affected by levels of N (Winter season).

Treatment	Knee high			Tasseling		
	N	P	K	N	P	K
$N_0P_1K_1$	0.123	0.039	0.213	0.296	0.090	0.67
$N_1P_1K_1$	0.193	0.063	0.297	0.393	0.115	0.87
$N_2P_1K_1$	0.206	0.081	0.340	0.487	0.141	1.08
$N_3P_1K_1$	0.243	0.101	0.387	0.610	0.174	1.33
$N_4P_1K_1$	0.270	0.105	0.376	0.703	0.198	1.51
$N_5P_1K_1$	0.300	0.109	0.403	0.793	0.223	1.67
$N_6P_1K_1$	0.326	0.110	0.396	0.870	0.221	1.79
$N_7P_1K_1$	0.353	0.115	0.427	0.890	0.226	1.86
$N_8P_1K_1$	0.348	0.106	0.383	0.913	0.217	1.89
F test	*	**	**	**	**	**
S.E. ±	0.0323	0.003	0.010	0.015	0.007	0.027
C.D. at 5%	0.097	0.010	0.030	0.044	0.020	0.080
1 %	0.136	0.014	0.043	0.062	0.028	0.113

A close look at Tables 11 and 12 indicated that significantly highest concentration of N (1.54 %) was observed to be in the 175 and 200 kg of N/ha followed by 150 and 125 kg N/ha. However, there was no significant differences among the treatments. The yield of N in 100 kg N/ha treatment was on par with 50 and 75 kg of N/ha, but was significantly superior to 25 kg N/ha and check ($N_0P_1K_1$) plots. The uptake was found to be highly significant as showed in Table 12 and graphically presented in Fig. 4. The highest uptake of N (80.76 kg/ha) in grain yield of maize was recorded by 200 kg of N/ha treatment.

Table 11 : % concentration of N, P and K in the maize plants at harvest stage, as affected by levels of N (Winter season).

Treatment	Grain			Stover		
	N	P	K	N	P	K
$N_0P_1K_1$	1.970	0.256	0.390	0.252	0.117	1.540
$N_1P_1K_1$	1.330	0.267	0.411	0.260	0.112	1.580
$N_2P_1K_1$	1.367	0.276	0.406	0.273	0.125	1.640
$N_3P_1K_1$	1.380	0.290	0.397	0.290	0.127	1.703
$N_4P_1K_1$	1.430	0.307	0.390	0.303	0.134	1.780
$N_5P_1K_1$	1.480	0.326	0.383	0.310	0.139	1.810
$N_6P_1K_1$	1.510	0.303	0.380	0.327	0.133	1.840
$N_7P_1K_1$	1.540	0.283	0.363	0.350	0.128	1.810
$N_8P_1K_1$	1.540	0.273	0.340	0.367	0.123	1.790
F test	**	*	N.S.	**	N.S.	**
S.E. ±	0.021	0.109	-	0.008	0.003	0.017
C.D.at 5 %	0.063	0.326	-	0.0278	-	0.051
1 %	0.0897	0.461	-	0.0335	-	0.072

Table 12 : Uptake of N, P and K (kg/ha) by maize crop at harvest stage, as affected by levels of N (Winter season).

Treatment	Grain			Stover		
	N	P	K	N	P	K
$N_0P_1K_1$	23.132	4.953	8.068	6.034	2.784	36.730
$N_1P_1K_1$	35.288	7.108	10.99	8.393	3.922	50.851
$N_2P_1K_1$	42.798	8.667	12.723	9.813	4.499	58.944
$N_3P_1K_1$	48.821	10.250	17.464	10.770	4.743	63.700
$N_4P_1K_1$	56.537	12.125	15.404	13.676	6.055	80.187
$N_5P_1K_1$	66.283	14.581	19.538	16.112	7.219	94.077
$N_6P_1K_1$	72.104	14.469	18.083	18.427	7.502	103.643
$N_7P_1K_1$	77.256	14.224	16.112	20.526	7.542	107.307
$N_8P_1K_1$	80.760	14.334	17.835	23.506	7.805	113.828
F test	**	**	**	**	**	**
S.E. ±	1.438	0.478	0.326	0.486	0.214	2.641
C.D.at 5 %	4.311	1.433	0.977	1.457	0.645	7.918
1 %	5.922	2.030	1.396	2.056	0.901	11.167

Almost similar trend in the different levels of N uptake on the stover yield were observed as in grain yield. These results corroborate the findings made by Phadke (1970).

In Tables 11 and 12, the effect of graded levels of N application on the concentration and uptake of P in grain yield were found to be significant. Whereas concentration of

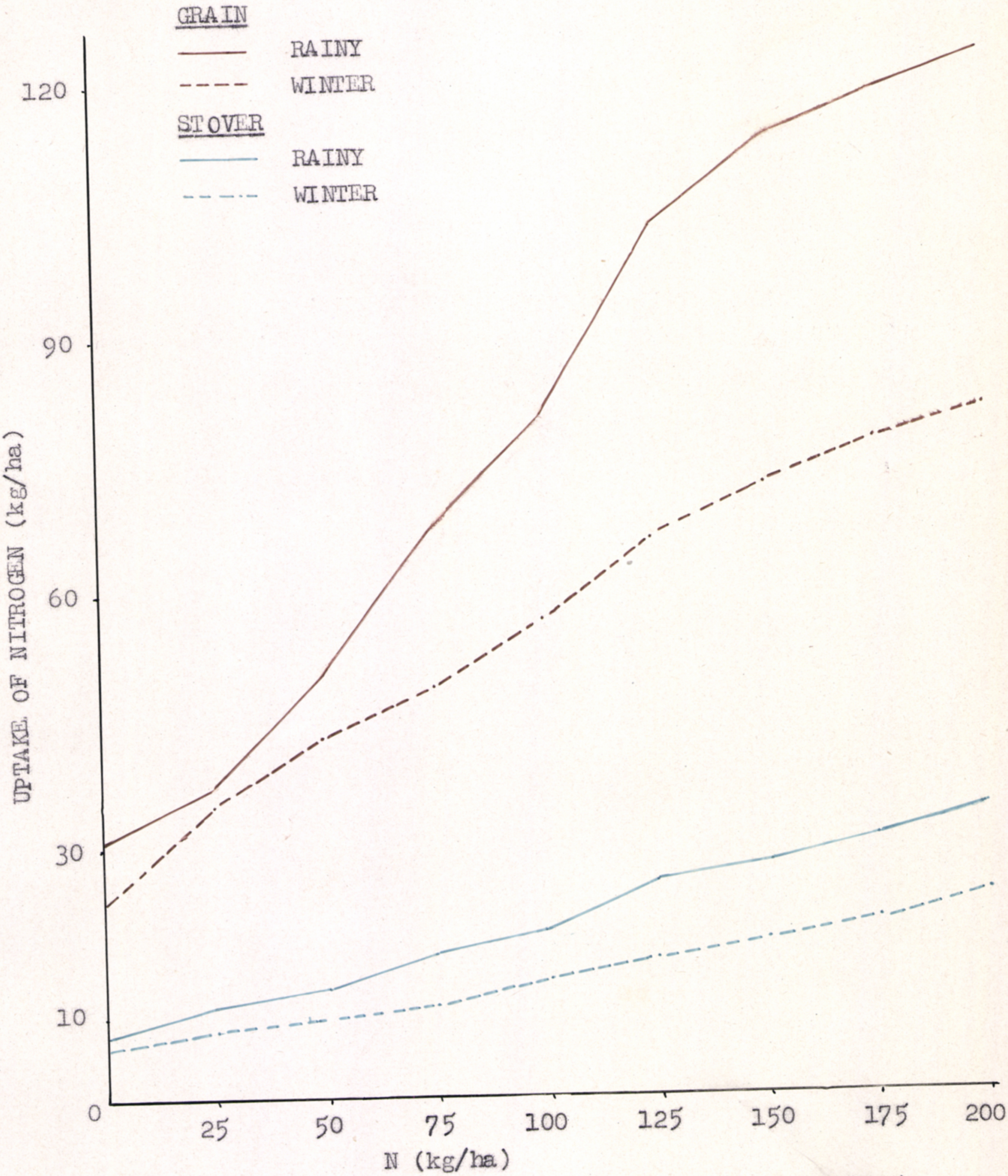

FIG. 4 : UPTAKE OF N (kg/ha) BY MAIZE CROP(GRAIN AND STOVER) AT HARVEST STAGE, AS AFFECTED BY LEVELS OF N DURING RAINY AND WINTER SEASONS.

K in grain was found to be non significant, but its uptake was found to be highly significant. It may be due to the effect of more grain production. In stover, the concentration of P was observed to be non significant, but the uptake of P in stover production showed the significant effect. The effect of stover production on the concentration and uptake of K was found to be highly significant.

It can be concluded from the foregoing observations (Rainy and Winter seasons) that the rainy season is better for the production of grain and stover and uptake of N than the winter season. Good performance of maize in rainy season may be attributed to the favourable climatic conditions existed as pointed out by Schrimpf (1966).

4.2. P Series :

4.2.1. Effects of graded levels of P on the dry matter productions at different stages :

Effect of graded levels of P application on the dry matter yield at knee high, tasseling and harvest (grain and stover) stages of corn in rainy and winter seasons were statistically tested and data are presented in Table 13 and grain and stover productions are graphically depicted in Fig. 5.

4.2.1.1. DM production in rainy season :

Data from Table 13 showed that the effect of graded

Table 13 : Effect of graded doses of P on the DM yield of maize at different stages of crop growth.

Treatment	Rainy season				Winter season			
	Dry matter				Dry matter			
	Knee high	Tasseling	Harvest		Knee high	Tasseling	Harvest	
			Grain	Stover			Grain	Stover
	g/plant		q/ha		g/plant		q/ha	
$P_0N_1K_1$	23.53	46.09	44.49	54.29	18.58	53.45	28.48	34.692
$P_1N_1K_1$	25.86	52.89	49.94	60.88	19.75	55.68	32.50	38.173
$P_2N_1K_1$	26.97	56.59	58.11	70.95	21.36	58.51	35.37	41.815
$P_3N_1K_1$	28.53	60.79	63.35	77.24	24.33	61.55	41.45	47.390
$P_4N_1K_1$	30.01	63.89	65.25	80.14	27.15	65.53	46.25	55.037
$P_5N_1K_1$	31.06	65.83	66.79	81.83	28.49	68.30	48.42	59.813
F test	*	**	**	**	**	**	**	**
S.E. ±	0.7599	0.852	3.191	3.997	0.4725	0.565	1.169	1.311
C.D. at 5 %	2.278	2.554	10.054	12.471	1.489	1.781	3.682	4.13
1 %	3.213	3.602	14.301	17.74	2.118	2.534	5.239	5.875

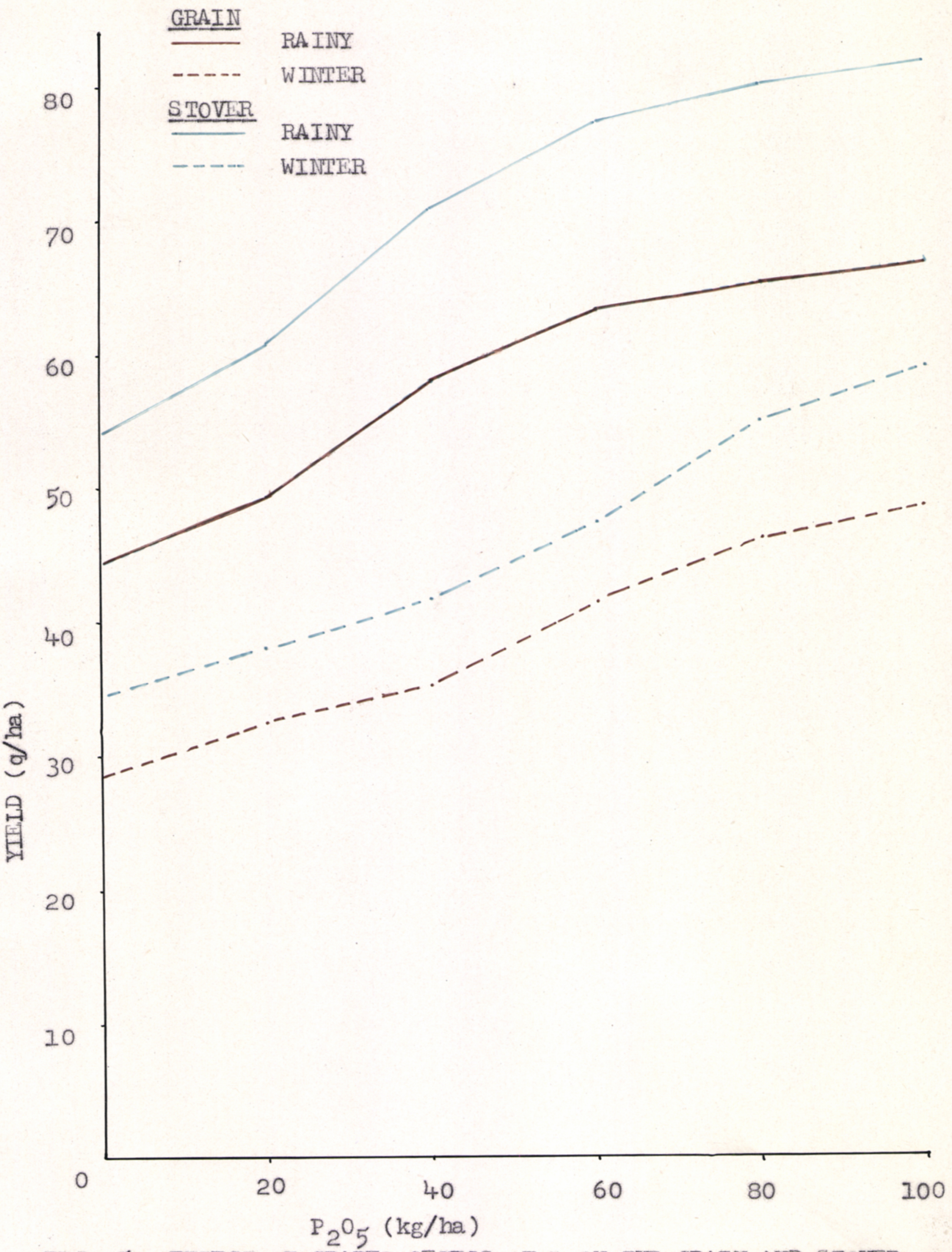

FIG. 5 : EFFECT OF GRADED LEVELS OF P ON THE GRAIN AND STOVER YIELD OF MAIZE AT DIFFERENT SEASONS.

levels of P on the DM production at knee high, tasseling and harvest (grain and stover) stages were found to be significant. Significantly, highest dry matter was found at knee high (31.06 g/plant), as well as at tasseling stage (65.83 g/plant) by the addition of 100 kg P_2O_5/ha followed by 80 kg P_2O_5/ha. However, these treatments were on par with each other. Significantly, highest grain (66.79 q/ha) and stover productions (81.83 q/ha) were observed by the application of P_2O_5 at the rate of 100 kg/ha. The treatment 60 kg of P_2O_5/ha was on par with 80, 100 kg of P_2O_5/ha in grain yield. Similarly, the stover production due to application of P_2O_5 at the rate of 40, 60, 80 and 100 kg/ha was on par. Significantly, the lowest dry matter was observed in the check plots. These observations support the findings made by Sexena and Gautam (1966), Singh and Brar (1973). and Walmsley and Baynes (1974) for response of maize to phosphate fertilization.

4.2.1.2. DM production in winter season :

It appeared from Table 13 that the treatment differences for the DM production at knee high, tasseling and harvest stage (Grain and Stover production) were found to be significant. Significantly, highest DM yield at knee high (28.49 g/plant) and harvest stages (48.42 q/ha of grain and 59.01 q/ha of stover) were obtained by the use of 100 kg P_2O_5/ha and was immediately followed by 80 kg P_2O_5/ha. But, there was no significant difference between these treatments. Significantly highest DM production at tasseling stage (68.30 g/plant) was recorded by the application of 100 kg P_2O_5/ha. The DM production in 60 kg P_2O_5/ha although inferior to 80 and 100 kg P_2O_5/ha, but was found to be superior to rest of the treatments.

The check plots ($P_0N_1K_1$) has recorded significantly lowest DM production at knee high, tasseling and harvest stage (grain and stover).

4.2.2. Concentration and uptake of P as influenced by the graded levels of phosphorus at various stages :

Mineral constituents namely P, N and K as influenced by P levels at knee high, tasseling and harvest stages were statistically calculated and are presented in Table 14, 15, 16, 17, 18, 19, 20 and 21.

4.2.2.1. Rainy season :

A perusal of the Table 14 revealed that the effect of P levels on the concentration of P was found to be highly significant. Significantly, highest P concentration (0.317 %) at knee high and (0.333 %) tasseling stage was observed to be in the 100 kg P_2O_5/ha followed by 80 kg P_2O_5/ha. However, they were on par with each other at both the stages. Significantly, lowest concentration of P was recorded in the $P_0N_1K_1$ treatments.

Table 14 : % concentration of P, N and K in the maize plants at different stages of growth as affected by levels of P (Rainy season).

Treatment	Knee high			Tasseling		
	P	N	K	P	N	K
$P_0N_1K_1$	0.192	1.013	1.440	0.233	0.747	1.493
$P_1N_1K_1$	0.212	1.026	1.126	0.263	0.773	1.506
$P_2N_1K_1$	0.230	1.083	1.123	0.273	0.800	1.193
$P_3N_1K_1$	0.269	1.160	1.113	0.285	0.817	1.503
$P_4N_1K_1$	0.291	1.213	1.106	0.310	0.810	1.490
$P_5N_1K_1$	0.317	1.180	1.070	0.333	0.810	1.487
F test	**	*	N.S.	**	*	N.S.
S.E. ±	0.007	0.031	0.019	0.010	0.011	0.006
C.D.at 5 %	0.023	0.097	-	0.028	0.035	-
1 %	0.032	0.138	-	0.039	0.050	-

Table 15 : Uptake of P, N and K (g/plant) by maize plant at different stages of growth as affected by levels of P (Rainy season).

Treatment	Knee high			Tasseling		
	P	N	K	P	N	K
$P_0N_1K_1$	0.045	0.236	0.266	0.108	0.343	0.690
$P_1N_1K_1$	0.055	0.266	0.293	0.139	0.410	0.797
$P_2N_1K_1$	0.061	0.290	0.300	0.154	0.453	0.843
$P_3N_1K_1$	0.077	0.330	0.316	0.173	0.497	0.913
$P_4N_1K_1$	0.087	0.366	0.330	0.198	0.517	0.950
$P_5N_1K_1$	0.098	0.366	0.336	0.220	0.533	0.977
F test	**	**	*	**	*	**
S.E. ±	0.003	0.008	0.011	0.007	0.031	0.012
C.D. at 5%	0.008	0.026	0.034	0.022	0.099	0.039
1 %	0.011	0.037	0.048	0.029	0.140	0.055

Almost similar trend of P uptake was also observed in uptake of P (Table 15) at knee high and tasseling stages as seen in concentration of P.

Effect of P levels on the concentration and uptake of N (Table 14, 15) was found to be highly significant. It may be attributed due to the effect of N on the increase in vegetative growth of the maize.

The effect of P_2O_5 application on the concentration of K (Table 14) at knee high and tasseling stage were found to be non significant. But the uptake of K (Table 15) was found to be significant by the addition of P at various levels.

The data reported in Table 16 indicated that highest concentration of P (0.323 %) in grain was observed by application of 100 kg P_2O_5/ha, followed by the rest of the treatments which were on par except check plots ($P_0N_1K_1$). The lowest concentration of P both in grain and stover was observed in check plots. Significantly, the highest concentration of P (0.143 %) in stover was recorded by application at the rate of 100 kg P_2O_5/ha.

The effects of P levels on the uptake of P (Table 17 and Fig. 6) was found to be highly significant in grain and stover. Significantly, lowest uptake of P was recorded by check plots. These results corroborate the finding made by Olsen (1962) for the corn and grain sorghum.

Table 16 : % concentration of P, N and K in the maize plants at harvest stage, as affected by levels of P (rainy season).

Treatment	Grain P	Grain N	Grain K	Stover P	Stover N	Stover K
$P_0N_1K_1$	0.197	1.333	0.457	0.082	0.283	1.597
$P_1N_1K_1$	0.280	1.470	0.453	0.083	0.296	1.740
$P_2N_1K_1$	0.290	1.533	0.443	0.090	0.310	1.600
$P_3N_1K_1$	0.300	1.567	0.433	0.116	0.320	1.570
$P_4N_1K_1$	0.310	1.600	0.423	0.127	0.326	1.510
$P_5N_1K_1$	0.323	1.597	0.413	0.143	0.350	1.493
F test	**	*	N.S.	**	-	-
S.E. ±	0.019	0.004	0.026	0.009	-	-
C.D. at 5 %	0.060	0.013	-	0.028	-	-
1 %	0.085	0.018	-	0.040	-	-

Table 17 : Uptake of P, N and K (kg/ha) by maize crop at harvest stage as affected by levels of P (Rainy season).

Treatment	Grain P	Grain N	Grain K	Stover P	Stover N	Stover K
$P_0N_1K_1$	8.772	59.37	20.35	4.452	15.394	86.731
$P_1N_1K_1$	13.94	73.11	22.58	5.072	18.00	105.830
$P_2N_1K_1$	16.72	88.88	25.67	6.328	21.922	113.430
$P_3N_1K_1$	18.84	98.34	27.32	8.429	24.534	121.290
$P_4N_1K_1$	20.05	104.19	27.36	10.086	26.097	120.780
$P_5N_1K_1$	21.39	106.49	27.40	11.575	28.546	122.090
F test	**	**	*	**	**	*
S.E. ±	0.655	3.956	1.123	0.304	1.092	5.958
C.D. at 5%	2.064	12.465	3.538	0.957	3.440	18.770
1 %	2.936	17.73	5.033	1.361	4.894	26.700

The concentration of N (Table 16) was found to be significant. The highest concentration of N (1.600 %) in grain was recorded by 80 kg of P_2O_5/ha ($P_4N_1K_1$), followed by 100 kg P_2O_5/ha which were on par in the grain. The increase in uptake of N (Table 17) may probably due to the effect of applied P on the uptake of nitrogen which has induced its availability in the soil. Patil (1978) has reported almost similar observation in sorghum.

The effect of graded levels of P on the concentration of K (Table 16) was found to be non-significant in grain. However, the effect on uptake of K in maize grain and stover was observed to be significant, indicating the influence of more dry matter production due to application at the rate of 125 kg N/ha with graded levels of P.

4.2.2.2. Winter season :

With a view to bring out clearly the effect of graded levels of P treatments, data on concentration of P, N and K are presented in Table 18. The treatment differences due to P levels on the concentration of P was found to be highly significant at knee high and tasseling stages. By increasing P levels, there was corresponding increase in concentration of P. Significantly, highest concentration of P was seen in the 100 kg P_2O_5/ha ($P_5N_1K_1$) at knee high and tasseling stage. Further, it would be observed that the

Table 18 : % concentration of P, N and K in the maize plants at different stages of growth, as affected by levels of P (Winter season).

Treatment	Knee high			Tasseling		
	P	N	K	P	N	K
$P_0N_1K_1$	0.193	0.993	1.156	0.216	0.696	1.533
$P_1N_1K_1$	0.211	1.053	1.136	0.237	0.703	1.526
$P_2N_1K_1$	0.225	1.080	1.116	0.250	0.710	1.536
$P_3N_1K_1$	0.238	1.120	1.100	0.260	0.703	1.533
$P_4N_1K_1$	0.267	1.180	1.096	0.290	0.696	1.530
$P_5N_1K_1$	0.297	1.166	1.090	0.310	0.703	1.526
F test	**	*	*	**	-	-
S.E. ±	0.0039	0.024	0.0117	0.007	-	-
C.D. at 5 %	0.012	0.075	0.037	0.021	-	-
1 %	0.017	0.106	0.053	0.029	-	-

Table 19 : Uptake of P, N and K (g/plant) by maize plant at different stages of growth as affected by levels of P (Winter season).

Treatment	Knee high			Tasseling		
	P	N	K	P	N	K
$P_0N_1K_1$	0.036	0.187	0.220	0.116	0.360	0.817
$P_1N_1K_1$	0.042	0.210	0.223	0.132	0.390	0.850
$P_2N_1K_1$	0.048	0.230	0.240	0.146	0.413	0.900
$P_3N_1K_1$	0.057	0.273	0.267	0.160	0.433	0.940
$P_4N_1K_1$	0.073	0.320	0.297	0.183	0.456	1.030
$P_5N_1K_1$	0.085	0.330	0.310	0.212	0.480	1.040
F test	**	-	-	**	-	**
S.E. ±	0.0011	-	-	0.004	-	0.018
C.D.at 5 %	0.003	-	-	0.012	-	0.055
C 1 %	0.005	-	-	0.017	-	0.079

concentration of P obtained in 80 kg P_2O_5/ha was found to be on par with 100 kg P_2O_5/ha at tasseling stage.

The uptake of P (Table 19) at knee high and tasseling stage were found to be almost similar, as seen in concentration of P at both the stages. The uptake of P in the 60 kg P_2O_5/ha treatment was significantly superior to either 20, 40 kg P_2O_5/ha. Significantly, lowest uptake of P was recorded in control plots.

The concentration and uptake of N (Table 18, 19) at both the stages were found to be significant.

Further, an appraisal of Table 20 revealed that the P treatment differences on the concentration of P in grains were found to be significant. Significantly, highest concentration of P (0.316 %) in grain was registered under 100 kg P_2O_5/ha immediately followed by 80, 60 and 40 kg P_2O_5/ha which were on par. Significantly lowest concentration of P (0.217 %) in grain was recorded in check plots ($N_0N_1K_1$). The concentration of P in stover was found to be significant.

It appeared from Table 21 (Fig. 6) that the treatment differences for uptake of P were found to be highly significant. The treatment $P_5N_1K_1$ (100 kg P_2O_5/ha) was on par with $P_4N_1K_1$ (80 kg P_2O_5/ha) in regards to the uptake P in grain. Significantly, lowest uptake of P (6.159 kg/ha) in grain was observed in check plot ($P_0N_1K_1$). Almost similar trend of P uptake was seen in the stover.

Table 20 : % concentration of P, N and K in the maize plants at the harvest stage, as affected by levels of P (Winter season).

Treatment	Grain			Stover		
	P	N	K	P	N	K
$P_0N_1K_1$	0.217	1.273	0.430	0.080	0.270	1.610
$P_1N_1K_1$	0.273	1.350	0.446	0.084	0.286	1.683
$P_2N_1K_1$	0.300	1.480	0.429	0.090	0.293	1.630
$P_3N_1K_1$	0.310	1.510	0.423	0.107	0.310	1.590
$P_4N_1K_1$	0.330	1.573	0.413	0.123	0.330	1.520
$P_5N_1K_1$	0.316	1.596	0.406	0.139	0.363	1.490
F test	**	**	*	**	-	-
S.E. ±	0.011	0.018	0.006	0.00141	-	-
C.D. at 5 %	0.034	0.057	0.019	0.0050	-	-
1 %	0.048	0.081	0.027	0.0063	-	-

Table 21 : Uptake of P, N and K (kg/ha) by maize crop at harvest stage, as affected by levels of P (Winter season).

Treatment	Grain			Stover		
	P	N	K	P	N	K
$P_0N_1K_1$	6.159	36.238	12.238	2.766	9.314	55.671
$P_1N_1K_1$	8.854	43.869	14.494	3.202	10.899	64.223
$P_2N_1K_1$	10.703	52.607	15.302	3.760	12.278	68.145
$P_3N_1K_1$	12.820	62.540	17.533	5.051	14.605	75.059
$P_4N_1K_1$	15.247	72.725	19.149	6.764	18.168	83.623
$P_5N_1K_1$	15.324	77.301	19.702	8.199	21.399	87.890
F test	**	**	*	**	**	**
S.E. ±	0.192	1.264	0.609	0.081	0.539	1.670
C.D. at 5 %	0.606	3.983	1.922	0.254	1.700	5.262
1 %	0.862	5.665	2.730	0.361	2.420	7.484

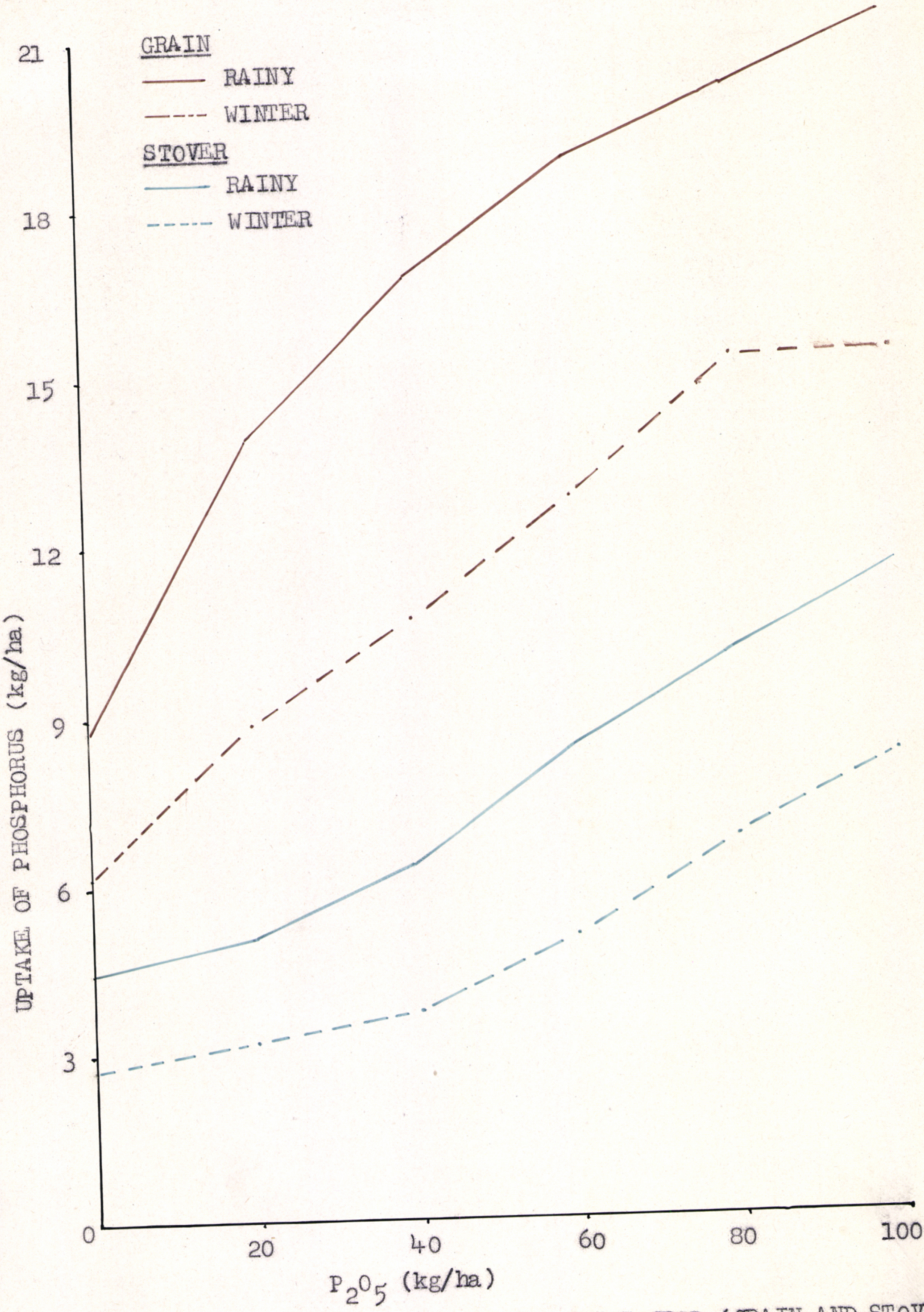

FIG. 6 : UPTAKE OF P_2O_5 (kg/ha) BY MAIZE CROP (GRAIN AND STOVER) AT HARVEST STAGE, AS AFFECTED BY LEVELS OF P_2O_5 DURING RAINY AND WINTER SEASON.

The data reported in Tables 20 and 21 indicated that the effect of P levels has significantly influenced in the concentration and uptake of N. Significantly, highest concentration of N (1.596 %) was found by 100 kg P_2O_5/ha followed by 80 kg P_2O_5/ha treatments. Significantly, highest uptake of N (77.301 kg/ha) was recorded at $P_5N_1K_1$. Similar trend of P uptake was also observed in stover.

Thus, from foregoing observations, it would be concluded that the economic optimum yield of both grain and stover production is better in the rainy season than winter season. 60 kg of P_2O_5/ha treatment has significantly produced economic optimum yield in rainy season.

4.3. Quantitative evaluation of N and P soil tests with response of maize through a modified Mitscherlich-Bray equation :

For quantitative evaluation of the relative efficiency of soil tests for N and P and graded doses of N and P fertilisers with response of maize, through a modified Mitscherlich-Bray equation were calculated mathematically.

4.3.1. The fitness of the curvilinear production :

4.3.1.1. Effect of different treatments of N on the grain and stover production and uptake of N, P and K :

The curvilinear production function equations (from equation 3.4) on the basis of actual yield obtained in regards to both grain and stover, and uptake of N, P and K as influenced by increasing levels of N were worked out in rainy and winter season and are reported (Table 22 and 23 Fig. 8) below.

Rainy season :

Grain yield		$Y = 20.950 + 0.3982\,X - 0.000653\,X^2$
	N	$Y = 24.313 + 0.6658\,X - 0.000752\,X^2$
	P	$Y = 5.713 + 0.1641\,X - 0.000432\,X^2$
	K	$Y = 8.797 + 0.1748\,X - 0.000419\,X^2$
Stover yield		$Y = 27.258 + 0.4587\,X - 0.000708\,X^2$
	N	$Y = 8.179 + 0.1145\,X - 0.000084\,X^2$
	P	$Y = 3.168 + 0.0707\,X - 0.000134\,X^2$
	K	$Y = 40.876 + 0.8890\,X - 0.001270\,X^2$

Winter season

Grain yield		$Y = 19.849 + 0.2460\,X - 0.000413\,X^2$
	N	$Y = 24.118 + 0.3850\,X - 0.000460\,X^2$
	P	$Y = 4.583 + 0.1054\,X - 0.000280\,X^2$
	K	$Y = 7.907 + 0.1380\,X - 0.000441\,X^2$
Stover yield		$Y = 24.618 + 0.2211\,X - 0.000120\,X^2$
	N	$Y = 6.287 + 0.0606\,X + 0.000130\,X^2$
	P	$Y = 2.716 + 0.0414\,X - 0.000076\,X^2$
	K	$Y = 36.310 + 0.49\,X - 0.000460\,X^2$

For predicting the response to N application, the calculated yield (grain and stover) and uptake of N, P and K were worked out on the basis of production function

Table 22 : Calculated yield of grain and stover (q/ha) and uptake of N, P and K (kg/ha) in rainy season.

Treatment	Grain				Stover			
	Yield	N	P	K	Yield	N	P	K
$N_0P_1K_1$	20.95	24.31	5.71	8.98	27.26	8.18	3.17	40.88
$N_1P_1K_1$	30.49	40.49	9.55	13.09	38.23	10.99	4.85	62.31
$N_2P_1K_1$	39.23	55.72	12.89	16.67	48.42	13.70	6.37	82.15
$N_3P_1K_1$	47.14	70.02	15.59	19.73	57.68	16.29	7.72	100.41
$N_4P_1K_1$	54.24	83.37	17.80	22.27	66.05	18.79	8.90	117.08
$N_5P_1K_1$	60.52	95.79	19.48	24.28	73.52	21.18	9.91	132.16
$N_6P_1K_1$	65.99	107.26	20.61	25.77	80.13	23.46	10.76	145.65
$N_7P_1K_1$	70.64	117.80	21.20	26.74	85.85	25.64	11.44	157.56
$N_8P_1K_1$	74.47	127.39	21.25	27.18	90.68	27.72	11.95	167.88

Table 23 : Calculated yield of grain and stover (q/ha) and uptake of N, P and K (kg/ha) in winter season.

Treatment	Grain				Stover			
	Yield	N	P	K	Yield	N	P	K
$N_0P_1K_1$	19.85	24.12	4.58	7.91	24.62	6.29	2.72	36.31
$N_1P_1K_1$	25.74	33.46	7.04	11.06	30.07	7.88	3.70	48.27
$N_2P_1K_1$	31.12	42.22	9.15	13.65	35.37	9.64	4.60	59.66
$N_3P_1K_1$	35.98	50.41	10.91	15.70	50.53	11.56	5.39	70.47
$N_4P_1K_1$	40.32	58.02	12.32	17.20	45.53	13.65	6.10	80.71
$N_5P_1K_1$	44.15	65.08	13.38	18.14	50.38	15.89	6.70	90.37
$N_6P_1K_1$	47.46	71.52	14.09	18.53	55.08	18.30	7.22	99.46
$N_7P_1K_1$	50.25	77.41	14.45	18.38	59.64	20.87	7.63	107.97
$N_8P_1K_1$	52.53	82.72	14.46	17.67	64.04	23.61	7.96	115.91

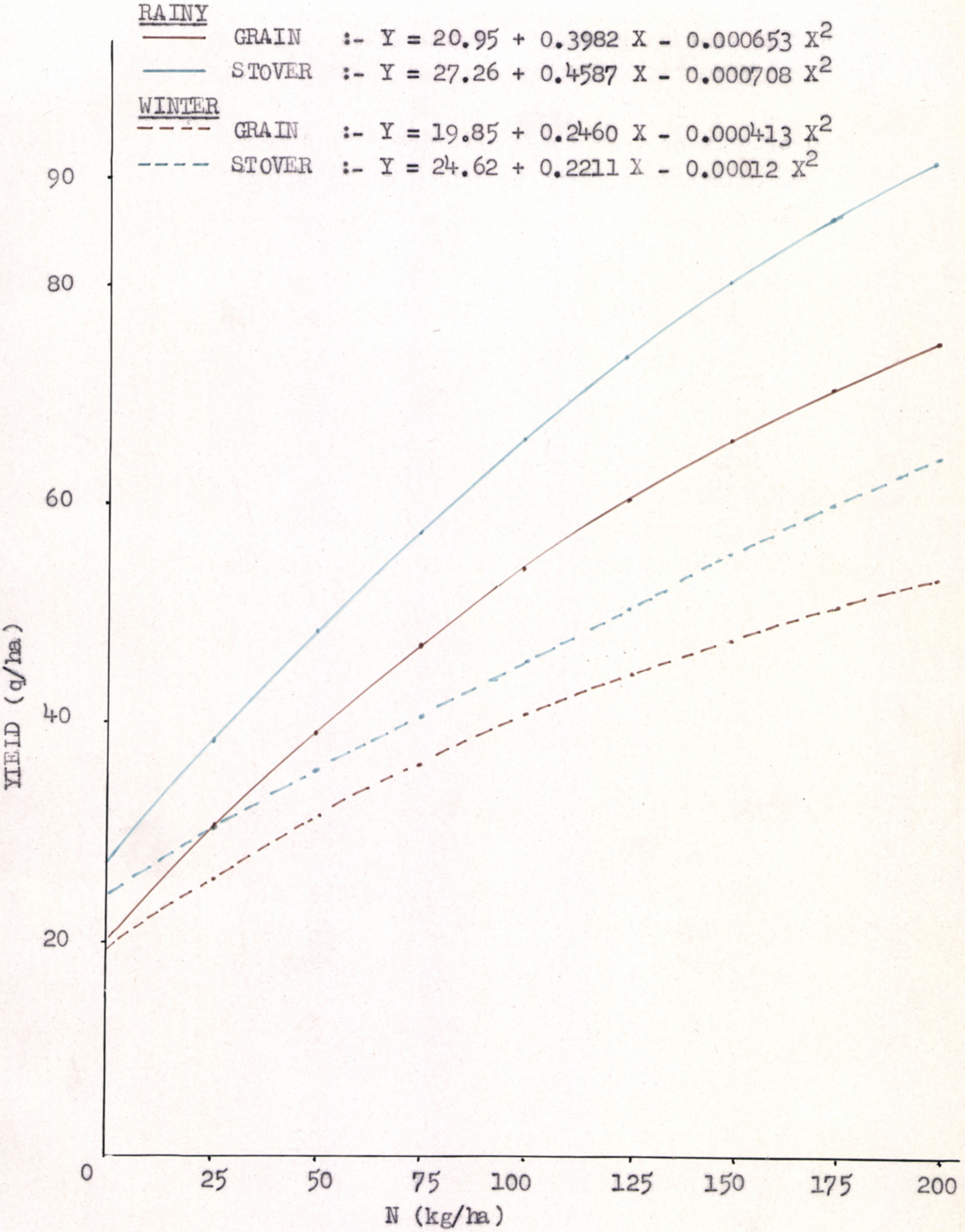

FIG. 7 : GRAIN AND STOVER RESPONSE TO N, OBTAINED BY USE OF POLYNOMIAL EQUATION IN DIFFERENT SEASONS.

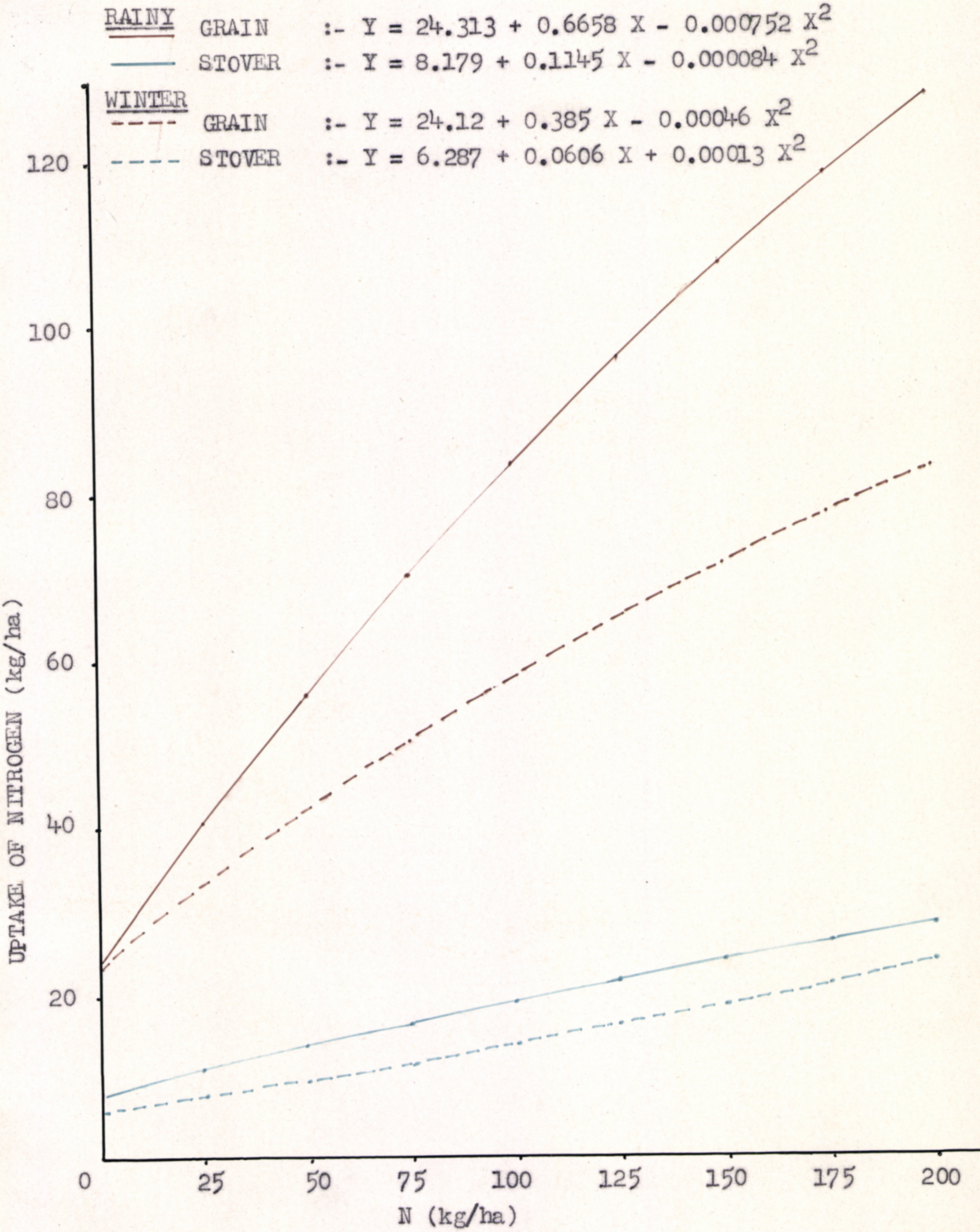

FIG. 8 : RELATION BETWEEN UPTAKE OF N (kg/ha) AND APPLIED N, OBTAINED BY USE OF POLYNOMIAL EQUATION IN DIFFERENT SEASONS.

equations and are presented in Tables 22 and 23 and depicted in Fig 7 and 8.

It would be observed from Tables 22 and 23 (Fig. 7 and 8) that the law of diminishing returns control the grain and stover production and nutrient plant composition relationship with regards to application of N. It appears that, with increase in graded levels of N, there was corresponding increase in yields of grain and stover and uptake of N, upto 150 kg of N/ha in both the seasons. After this, the rate of increase was reduced.

Correlation coefficients between the observed and calculated yields were worked out to assess the validity of using these c_1 and c values in these calculations. The coefficients for grain 0.991**, stover 0.991** in rainy season and for grain 0.999**, stover 0.993** in winter season (Table 24), suggesting a highly significant close relationship between the calculated and actual observed yield. There was a significant curvilinearity in regression calculated by the second degree polynomial in which case the coefficient of correlation existed were of the high order. This proves the suitability of the $KMnO_4$ method for determining c_1 and c values for vertisols in Sawargaon series. The degree of coefficient of determinations between the actual and calculated yields in regards to grain and stover in rainy and winter seasons were 99.30, 99.30 and 99.80, 98.60 respectively. This shows that equation relates the yield of

Table 24 : Coefficient of correlation (r) between actual and calculated yield (q/ha) in rainy and winter seasons for N series.

Treatment	Rainy season				Winter season			
	Grain yield		Stover yield		Grain yield		Stover yield	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
0	24.54	20.95	29.90	27.26	20.37	19.85	23.79	24.67
25	28.22	30.50	38.33	38.28	26.61	26.74	32.20	30.07
50	35.91	39.23	43.69	48.42	31.32	31.12	35.88	35.37
75	46.47	47.14	56.71	57.68	35.39	35.98	37.32	40.53
100	52.70	54.24	64.17	66.05	39.55	40.32	45.04	45.53
125	64.56	60.52	78.73	73.53	44.78	44.15	51.96	50.38
150	68.71	65.99	81.43	80.13	47.73	47.46	56.32	55.08
175	70.97	70.64	86.92	85.85	50.12	50.25	50.14	59.64
200	75.15	74.47	88.01	90.68	52.44	52.53	63.63	64.04
	r = 0.991**		r = 0.991*		r = 0.999**		r = 0.993**	
	Y = 1.8995 + 0.9598 X		Y = 0.0053 + 1.001 X		Y=0.0844 + 0.998 X		Y = 0.001705 + 1.00004 X	

both grain and stover to the added nutrients in the soil. These results are in close confirmity as reported by Dhanapalan *et al.* (1973).

4.3.1.2. Effect of different treatments of P on the yield of grain and stover and uptake of P, N and K in various seasons :

The curvilinear production function equations (from equation 3.4) on the effect of different graded doses (increasing level) of P on the basis of actual yield of both grain and stover, and uptake of P, N and K were worked out in rainy and winter seasons.

Rainy season :

Grain yield $Y = 43.704 + 0.4316\ X - 0.00199\ X^2$

N $Y = 58.395 + 0.9253\ X - 0.00441\ X^2$

P $Y = 9.137 + 0.2330\ X - 0.00114\ X^2$

K $Y = 20.075 + 0.1766\ X - 0.00103\ X^3$

Stover yield $Y = 53.311 + 0.5257\ X - 0.00237\ X^2$

N $Y = 15.186 + 0.1780\ X - 0.0046\ X^2$

P $Y = 4.231 + 0.0489\ X - 0.00027\ X^2$

K $Y = 83.073 + 0.8698\ X - 0.00542\ X^2$

Winter season :

Grain yield $Y = 28.152 + 0.2169\ X - 0.00007\ X^2$

N $Y = 35.423 + 0.4740\ X - 0.00042\ X^2$

P $Y = 6.082 + 0.1440\ X - 0.00048\ X^2$

K $Y = 12.266 + 0.1000\ X - 0.00024\ X^2$

Stover yield $Y = 34.341 + 0.1700\ X + 0.00080\ X^2$

N $Y = 9.414 + 0.4510\ X + 0.00076\ X^2$

P $Y = 2.734 + 0.01300\ X + 0.00043\ X^2$

K $Y = 56.110 + 0.3360\ X - 0.00013\ X^2$

For predicting the response to P application, the calculated yield (grain and stover) and uptake of P, N and K were worked out on the basis of production function equations and are reported in Tables 25 and 26 (Fig. 9 and 10).

It would be seen from Table 25 and 26 that with an increase in different levels of P, there was corresponding increase in yield of grain, stover and uptake of P, upto the 60 kg P_2O_5/ha in rainy and 40 kg of P_2O_5/ha in winter seasons. Further, the observed rate of increase was declined. It has indicated that there is a quadratic relationship between the fertiliser dose for P and yields of both grain and stover.

Correlation coefficients between the observed and calculated yields were worked out. It would be observed from Table 27 that a highly significant correlation existed between the calculated and actual yields. The coefficient of correlations were ... grain = 0.995**, Stover = 0.995** in rainy season and grain = 0.993**, stover = 0.995** in winter season.. The degree of coefficient of determinations between the actual and calculated yield in regards to grain and stover in rainy and winter seasons were 98.90, 98.90, 98.60, 98.90 respectively.

Table 25 : Calculated yield of grain and stover (q/ha) and uptake of P, N and K (kg/ha) in rainy season.

Treatment	Grain				Stover			
	Yield	P	N	K	Yield	P	N	K
$P_0N_1K_1$	43.70	9.14	58.40	20.08	53.31	4.23	15.18	88.07
$P_1N_1K_1$	51.54	13.34	75.14	23.19	62.87	5.10	18.56	103.30
$P_2N_1K_1$	57.78	16.63	88.35	25.48	70.54	5.76	21.57	114.19
$P_3N_1K_1$	62.43	19.01	98.03	26.95	76.30	6.21	24.22	120.75
$P_4N_1K_1$	65.49	20.48	104.18	27.58	80.19	6.45	26.51	122.97
$P_5N_1K_1$	66.95	21.04	106.80	27.39	82.14	6.47	28.43	120.85

Table 26 : Calculated yield of grain and stover (q/ha) and uptake of P, N and K (kg/ha) in winter season

Treatment	Grain				Stover			
	Yield	P	N	K	Yield	P	N	K
$P_0N_1K_1$	28.15	6.08	35.42	12.26	34.34	2.73	9.41	56.11
$P_1N_1K_1$	32.46	8.72	44.73	14.17	38.14	3.16	10.62	62.77
$P_2N_1K_1$	36.71	11.07	53.71	15.88	42.58	3.94	12.43	69.34
$P_3N_1K_1$	40.92	12.99	62.34	17.40	47.67	5.06	14.85	75.80
$P_4N_1K_1$	45.06	14.53	70.65	18.73	53.40	6.52	17.87	82.15
$P_5N_1K_1$	49.16	15.68	78.62	19.86	59.71	8.33	21.51	88.41

Table 27 : Coefficient of correlation (r) between actual and calculated yield (q/ha) in rainy and winter seasons for P series.

Treatment (P_2O_5 kg/ha)	Rainy season				Winter season			
	Grain yield		Stover yield		Grain yield		Stover yield	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
0	44.49	43.70	54.29	53.31	28.48	28.15	34.59	34.34
20	49.94	51.54	60.88	62.88	32.50	32.46	38.17	38.14
40	58.11	57.78	70.95	70.53	35.37	36.72	41.82	42.69
60	63.35	62.43	77.24	76.03	41.45	40.92	47.39	47.67
80	65.25	65.49	80.14	80.16	46.25	45.07	55.04	53.40
100	66.79	66.95	81.83	82.13	48.52	49.16	59.01	59.77
	r = 0.995**		r = 0.995**		r = 0.993**		r = 0.995**	
	Y = 0.5845 + 0.9398X		Y = 0.7088 + 0.9903X		Y = 0.5987 + 0.984 X		Y = 0.0493 + 1.0015 X	

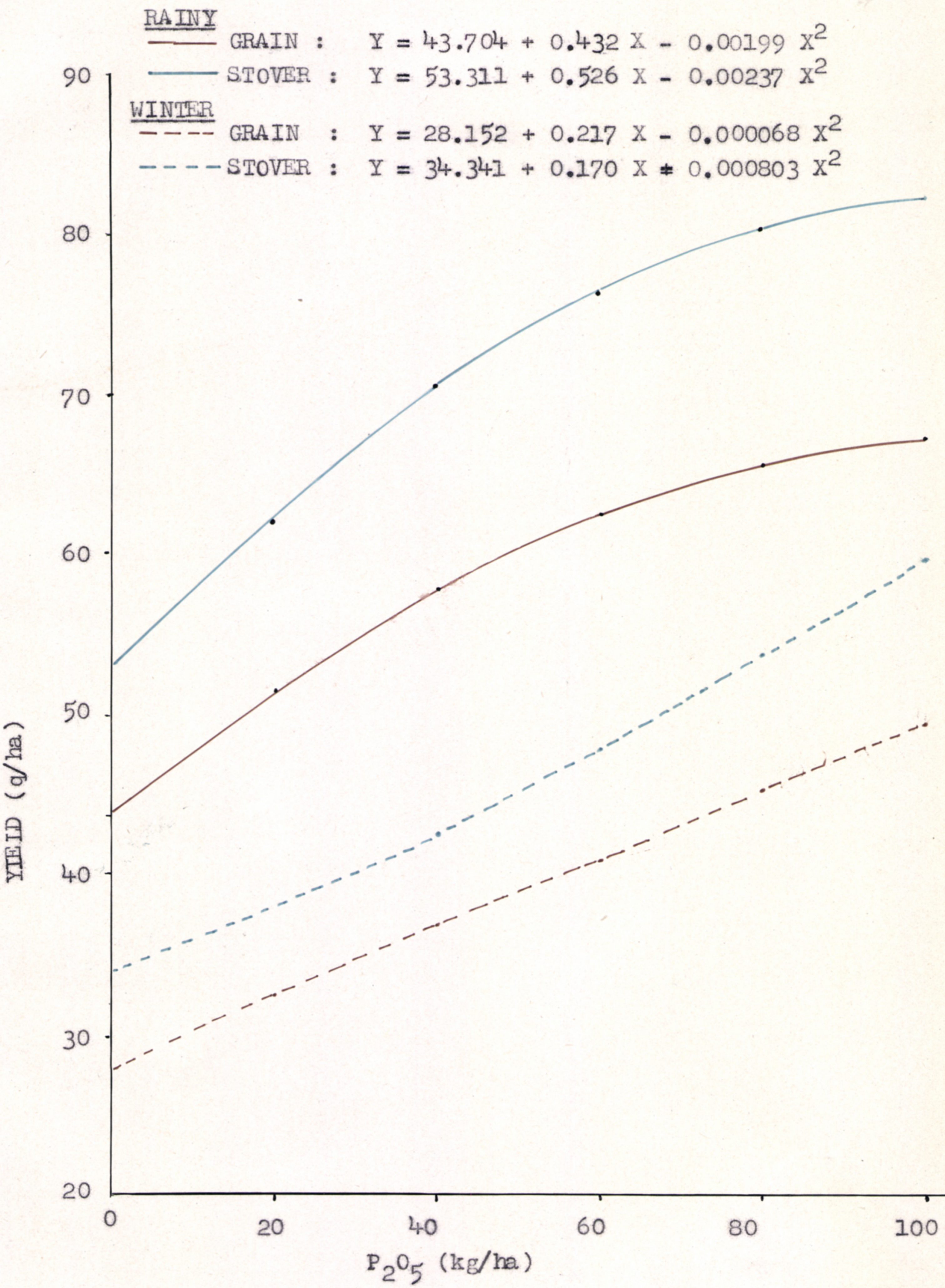

FIG. 9 : GRAIN AND STOVER RESPONSE TO P_2O_5, OBTAINED BY USE OF POLYNOMIAL EQUATION IN DIFFERENT SEASONS.

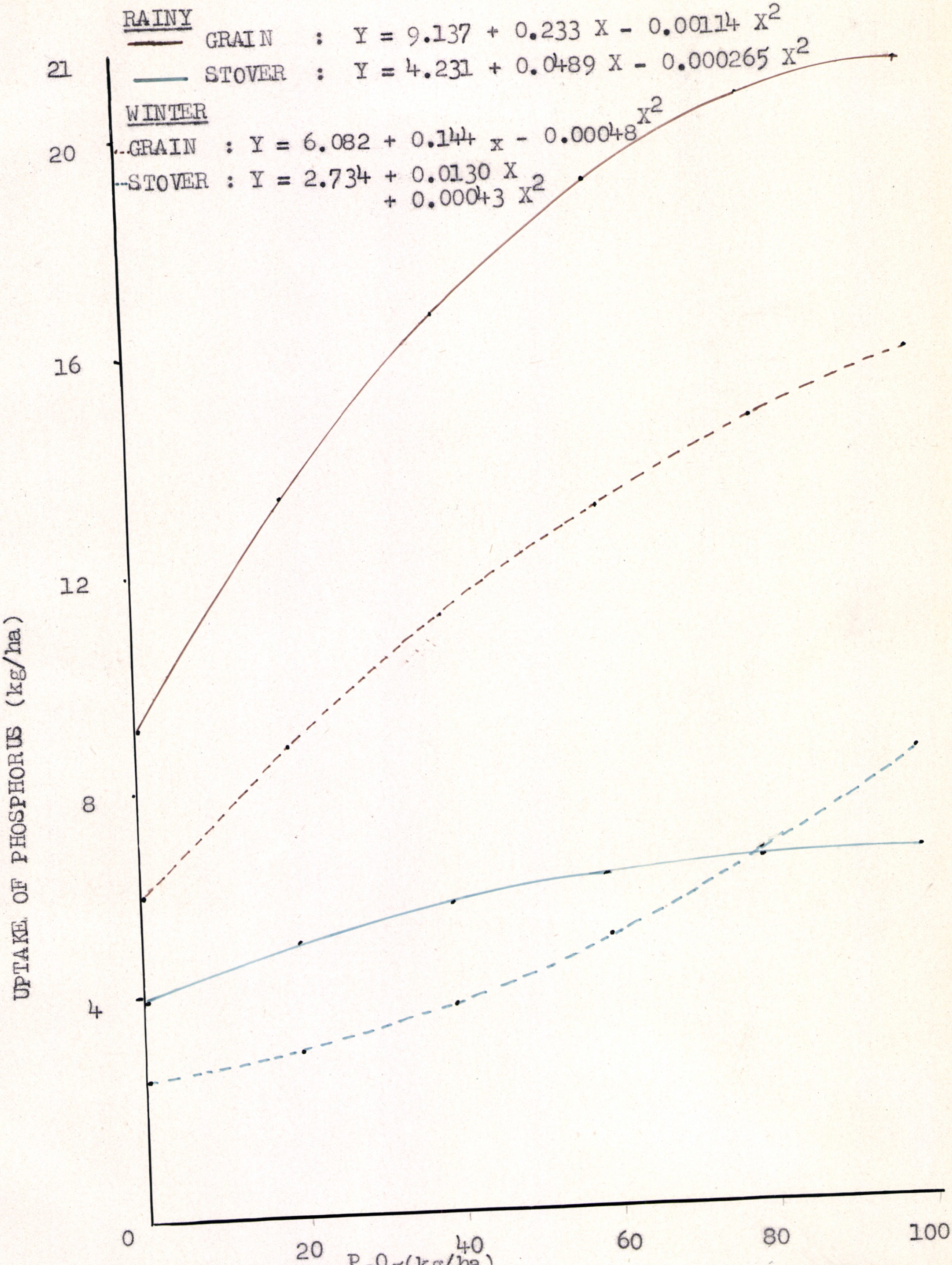

FIG. 10 : RELATION BETWEEN UPTAKE OF P_2O_5 (kg/ha) AND APPLIED N OBTAINED BY USE OF POLYNOMIAL EQUATION IN DIFFERENT SEASONS.

This shows that the equation relates the yield of both grain and stover to the nutrient (P) content in the soil.

4.4 Quantitative measure for the relative efficiency of soil and fertiliser nutrients :

The response of maize plant to added nutrients in the soil can be expressed by curvilinear functions and logarithmic functions as postulated by Mitscherlich (1909). These logarithmic functions were modified by Bray (1958). He developed the equation on the basis of efficiency factor for soil and added nutrient. The modified equation is as $\log (A-Y) = \log A - c_1 b - cx$.

Two experiments were conducted with graded levels of N and P, for evaluating the effect on grain and stover production and uptake of N and P in rainy season, as well as in winter season. The data obtained, are used for calculating,

a) the theoretical maximum yield,
b) evaluation of constants, c_1 and c of Mitscherlich-Bray equation,
c) Baule units for soil and fertiliser nutrients, and
d) the site specific fertiliser formulations for the maize.

a) Theoretical maximum yield :

The theoretical maximum yield (value of A) was

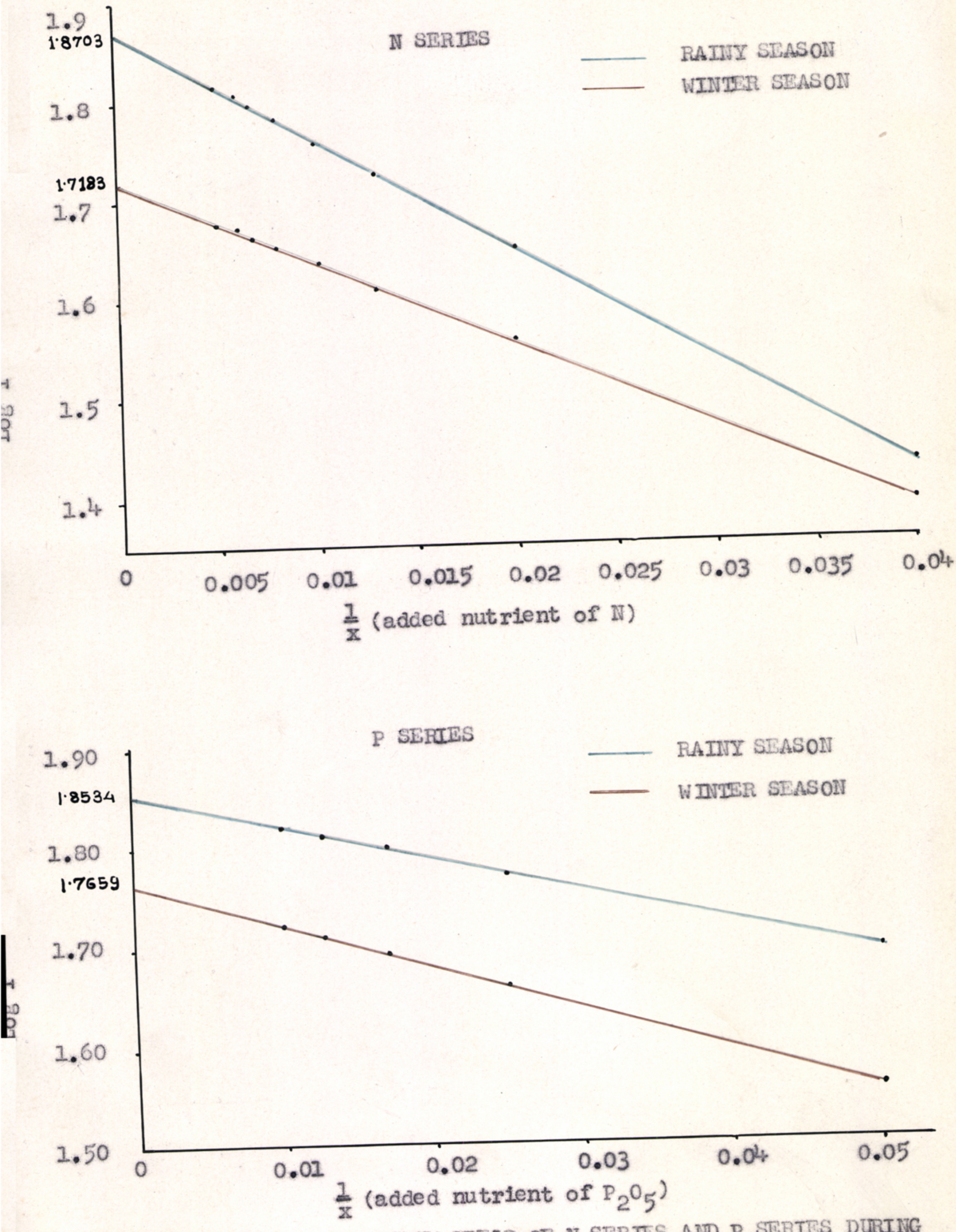

FIG. 11 : THEORETICAL MAXIMUM YIELD OF N SERIES AND P SERIES DURING RAINY AND WINTER SEASONS.

calculated by plotting log Y against 1/x and extrapolating to $1/x \longrightarrow 0$, where Y is the yield obtained for the applied nutrient 'X' (Ranganathan et al., 1969). The theoretical maximum yield as calculated by using the equation mentioned in materials and methods, are presented in Table 28 and are plotted in the Fig. 11.

It was observed that the theoretical maximum yield for the rainy and winter seasons (from equations 3.1, 3.2 and 3.3) were 74.17 q/ha and 52.28 q/ha for N series and 71.36 q/ha and 58.33 q/ha for P series, respectively. It indicates that, by employing N and P soil tests and with maximum added nutrient (200 kg of N/ha and 100 kg P_2O_5/ha), it is possible to obtain a maximum yield under the N and P experimental conditions separately.

b) Quantitative evaluation of constants c_1 and c of the Mitscherlich-Bray equation :

The efficiency factor for native soil nutrient (c_1), represents the ability of the plant to use the native soil nutrient for production of yield or the amount of dry matter.

The efficiency factor for added fertiliser nutrient (c) represents the ability of plant to use the added nutrient for producing the yield or the amount of dry matter.

The c_1 and c factors calculated for N and P series

Table 28 : Theoretical maximum yield of N series (Rainy and Winter seasons).

Treatment	1/x	Rainy season		Winter season	
		Yield q/ha	Calculated log Y(A)	Yield q/ha	Calculated log Y(A)
N Series					
0	—	24.54	—	20.373	—
25	0.04	28.22	1.4230	26.610	1.3937
50	0.02	35.91	1.6467	31.323	1.5560
75	0.013	46.47	1.7212	35.393	1.6101
100	0.01	52.7	1.7585	39.553	1.6371
125	0.008	64.56	1.7809	44.783	1.6534
150	0.00671	68.71	1.7958	47.725	1.6642
175	0.00571	70.97	1.8064	50.12	1.6719
200	0.005	72.15	1.8144	52.44	1.6777
Theoretical maximum yield			1.8703		1.7183
q/ha			74.17		52.28
P Series					
0	—	44.49	—	28.48	—
20	0.05	49.94	1.6946	32.50	1.5567
40	0.025	58.11	1.774	35.37	1.6608
60	0.0167	63.35	1.8005	51.45	1.6956
80	0.0125	65.25	1.8137	46.25	1.7129
100	0.01	66.79	1.8216	48.52	1.7233
Theoretical maximum yield			1.8534		1.7659
q/ha			71.36		58.33

separately for rainy and winter seasons alongwith ratio of c_1/c are presented in Table 29.

Table 29 : Efficiency coefficients of soil test and added N (at its sufficiency level).

Season	c_1	Baule equivalents of soil nutrient	Baule unit	c	Baule equivalent of added nutrient	c_1/c
Rainy						
1. N series	0.00134	224.627	0.824	0.00866	34.758	0.1547
2. P series	0.02260	13.320	1.408	0.00839	35.876	2.6937
Winter						
1. N series	0.00309	97.410	1.970	0.01199	25.104	0.2577
2. P series	0.03940	7.640	2.618	0.00560	53.730	7.0380

The data reported in Table 29 would reveal that the efficiency factor c_1 for soil and c for added nutrient to N and P series were found to be higher in winter season compared to rainy season except the value of c, which was comparatively smaller for 'P' series in winter season. Further, it would be observed that the efficiency of the fertiliser form (c) was better than the soil form (c_1) in N series and reverse was the case in P series for both rainy and winter seasons. Biddappa and Patnaik (1977) also obtained similar results and indicated that the efficiency factor for added N and P were as an index of responsiveness of the crop.

The ratio c_1/c was then calculated to ascertain which form of nutrient is more efficient than the other. Further, it would be observed that the ratio of c_1/c for N series in both rainy and winter seasons were seen to be less than one, indicating a good response to the N fertilization to soil. In case of P, the ratio of c_1/c exceeded the value of one, which indicated lower response to P fertilization in the soil. Further, it would be observed that the values of ratio of c_1/c found to be more in winter season than that in rainy season, indicating higher efficiency of both native soil nutrient and added nutrient in rainy season. Similar observations were also reported by Dhanapalan *et al.* (1973) and Biddappa and Patnaik (1977).

c) Calculation of Baule units for soil and fertilizer nutrients :

The Baule unit, represents the unit of fertilizer or any growth factor be taken as that amount required to produce the yield, i.e. 50 per cent of the maximum possible. It is calculated by using the following equation,

$$\log (A-Y) = \log A - 0.301 (x).$$

Where, 0.301 is the Mitscherlich constant and x represents the number of units i.e. 1, 2, 3 etc.

Yield percentage according to Baule unit of fertiliser for N and P series in rainy and winter seasons were calculated and are presented in Table 30.

Table 30 : Yield percentage according to unit of fertiliser.

Unit factor (x)	Rainy season				Winter season			
	Nitrogen		Phosphorus		Nitrogen		Phosphorus	
	Yield	Increase in yield	Yield	Increase in yield	Yield	Increase in yield	Yield	Increase in yield
	%							
0	0	-	0	-	0	-	0	-
1	30.07	37.07	35.68	35.68	26.14	26.14	29.16	29.16
2	55.62	18.55	53.52	17.84	39.21	13.07	43.75	14.59
3	64.89	9.27	62.43	8.92	45.75	6.54	51.03	7.28
4	69.53	4.63	66.89	4.46	49.01	3.26	54.68	3.65
5	71.85	2.31	69.13	2.23	50.64	1.63	56.50	1.82
6	-	-	-	-	51.46	0.81	-	-
7	-	-	-	-	51.87	0.40	-	-

It would be observed from Table 30 that the per cent increase in the yield reduced with an increase in the per cent yield. The yield per cent for growth factor 5 was comparatively more for N and P in rainy season than in winter season. It appears that the rainy season is better for the production of grain than the winter season. The higher yield in rainy season may be attributed due to the existence of favourable climatic conditions in rainy seasons as rightly pointed out by Schrimpf (1966).

These results are inconfirmation to those reported by Bray (1958). He opined that the efficiency of c_1 and c factors is dependent on the degree of competition between roots of adjoining plants caused by differences in planting rate and pattern and habit of the plant root system in the soil.

d) Site specific recommendation of N and P :

The site specific recommendation of N and P based on modified Mitscherlich-Bray equation, for rainy and winter seasons, were calculated for obtaining the expected yield or possible yield of grain and are reported in Table 31.

As evidenced, by the data in Table 31, it would be observed that, there is no need for adding the N and P fertiliser for 0 (0 per cent) Baules in both the seasons. Further, it has been observed that for obtaining 1 (50 per cent) Baule, there is a need of adding 6.116 kg of N/ha but there is no need to add P in rainy season and N and P in winter seasons. As the number of Baules increases, there was corresponding increase in both N and P requirement of maize in both the seasons. For obtaining 5 (96.87 per cent) Baule of the theoretical maximum yield, it is required to add N at the rate of 145.50 kg/ha which is a economic optima ,

Table 31 : Site specific recommendation of N and P for both rainy and winter seasons based on Mitscherlich-Bray equation.

No. of Baules required	Theoretical maximum yield q/ha	0	1	2	3	4	5	6	7
		0%	50	75	87.5 %	93.75	96.87	97.38	98.34
Rainy									
Kg of N/ha	74.17	0	6.116	40.873	75.639	110.3999	145.150	-	-
Kg of P_2O_5/ha	71.36	0	0	21.650	57.116	92.994	128.890	-	-
Winter									
Kg of N/ha	5[illegible].28	0	0	0.733	25.834	50.944	76.0474	90.58	92.82
Kg of P_2O_5/ha	58.33	0	0	0	20.535	74.26	128.05	-	-

while for achieving 3 (87.5 per cent) Baules of the theoretical maximum yield, the economical optimum requirement of P to be added to the soil was 57.116 kg of P_2O_5/ha in rainy seasons.

Further, it would be visualized that in winter season, there is no need to add N or P for achieving 1 (50 per cent) Baule of the theoretical maximum yield. However, for higher value of Baule unit, the N and P fertilizer requirements will be in increasing rate. The rate of 92.82 kg of N/ha and 74.26 kg P_2O_5/ha was considered optimum for obtaining 7 (98.43 per cent) and 4 (93.75 per cent) Baules of theoretical maximum yield respectively. Almost similar observations were also reported by Biddappa and Patnaik (1977) for rice crop in rainy and winter seasons of Cuttack.

4.5. Fertilizer formulations for routine soil testing laboratories :

The site specific N and P fertilizer formulations (Tables 32 and 33) based on efficiency of c_1 for b and c for x form were calculated for rainy and winter seasons by using the equations i.e. -

Rainy season

N :- $\log (100-Y) = \log 100 - 0.00134\, b - 0.00866\, x$

P :- $\log (100-Y) = \log 100 - 0.0226\, b - 0.00839\, x$

Winter season

N :- $\log (100-Y) = \log 100 - 0.00309\, b - 0.01199\, x$

P :- $\log (100-Y) = \log 100 - 0.0394\, b - 0.0056\, x$.

Table 32 : Fertiliser recommendation chart for rainy season.

Soil test value	Amount of N/P ferti. to be applied for the expected yield				
	75	80	85	90	95
		Nitrogen			
100	54.053	65.24	79.665	100.00	134.76
150	46.316	057.506	71.928	92.26	127.02
200	38.57	49.77	64.19	84.53	119.28
250	-	42.03	56.46	76.79	111.55
300	-	39.60	48.72	69.053	103.81
350	-	-	40.98	61.32	96.07
400	-	-	33.25	53.58	88.34
500	-	-	-	38.106	72.86
600	-	-	-	-	57.39
		Phosphorus			
10	44.82	56.38	71.26	92.25	128.13
20	17.89	29.44	44.33	65.32	101.19
30	-	-	17.39	38.38	74.26
40	-	-	-	11.44	47.318
50	-	-	-	-	20.38
60	-	-	-	-	-
80	-	-	-	-	-

Table 33 : Fertilizer recommendation chart for nitrogen (Winter season).

Soil test value	Amount of N/P ferti. to be applied for the expected yield				
	75	80	85	90	95
	%				
			Nitrogen		
100	24.45	32.53	42.94	57.63	82.74
150	11.52	19.60	30.016	44.70	69.81
200	-	6.76	17.17	31.85	56.96
250	-	-	4.25	18.93	44.036
300	-	-	-	6.09	31.19
350	-	-	-	-	18.31
400	-	-	-	-	-
500	-	-	-	-	-
600	-	-	-	-	-
			Phosphorus		
10	37.16	54.46	76.77	108.21	161.96
20	-	-	6.41	37.86	91.61
30	-	-	-	-	21.25
40	-	-	-	-	-
50	-	-	-	-	-
60	-	-	-	-	-
70	-	-	-	-	-
80	-	-	-	-	-

An appraisal of Table 32 and 33 would reveal that with the increase in the soil test values, there was a corresponding decrease in N and P requirements of maize. In other words, higher the native soil nutrients for N and P the less will be contribution from the N and P fertilisers. Further, it cannots that, with the increase in percentage expected or possible yield, there was a corresponding increase in fertiliser requirement for the same soil test value.

By the use of modified Mitscherlich-Dray equation and the efficiency factor of c_1 and c values, obtained in this investigation, the practical fertiliser requirements for maize either in rainy or in winter seasons can be calculated on the basis of soil test value before fertilization.

In routine soil testing instead of using arbitrary soil test rating i.e. low, medium and high fertility classes (Muhr et al., 1965), if the efficiency factors for c_1 and c are used, the correct appraisal of the N and P fertiliser requirements of maize can be made. It is also possible to predict precisely, the percentage yield to be obtained from the crop. On the basis of investigations, it is suggested that once, the constants c_1 and c are established, the soil test result could conveniently be used to calculate the fertiliser need and percentage response obtainable to maize crop during subsequent few years.

Chapter Opener Page

Chapter V

SUMMARY AND CONCLUSIONS

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Chapter V

SUMMARY AND CONCLUSION

For confirming the validity of the Mitscherlich-Bray concepts and thereby formulating a sound fertiliser recommendation, four field experiments were conducted in 1978-79 on the Savargaon series of vertisols of Mahatma Phule Krishi Vidyapeeth Research Farm, Rahuri. In this investigation, two field experiments were taken up in rainy and winter seasons each with the graded levels of N and P separately with maize (*Zea mays* L.) hybrid Ganga Safed-2 as an indicator crop. The salient findings of the investigation are as under -

1. More dry matter production and more uptake of N are recorded by the application of 125 kg N/ha in rainy season and 175 kg N/ha in winter season at knee high and tasseling stages of maize.

2. More DM production and more uptake of P are recorded by the application of 60 kg P_2O_5/ha in rainy season and 80 kg of P_2O_5/ha in winter season at knee high and tasseling stages.

3. Application of 125 kg of N/ha in rainy and 175 kg N/ha in winter season resulted in achieving economic optimum yield of corn (grain = 64.56 and 50.12 q/ha and stover = 78.73 and 59.14 q/ha respectively) and uptake of N.

4. Application of 60 kg of P_2O_5/ha in rainy and 80 kg of P_2O_5/ha in winter season resulted in obtaining economic optimum yield of corn (grain = 63.35 and 46.25 q/ha and stover = 77.24 and 55.04 q/ha respectively) and uptake of P.

5. The production function equations for predicting the fertilizer response of grain are calculated.

Rainy season :

For N :- $Y = 20.950 + 0.3982\ X - 0.000653\ X^2$

For P :- $Y = 43.704 + 0.4316\ X - 0.001990\ X^2$

Winter season :

For N :- $Y = 19.849 + 0.2460\ X - 0.000413\ X^2$

For P :- $Y = 28.152 + 0.2169\ X - 0.000070\ X^2$.

6. There is a highly significant curvilinearity in regression for N and P application, calculated by the second degree of polynomial and the coefficients of correlation between actual and calculated yield were of high order (r = 0.99 and coefficient of determinations = 98 %).

7. The theoretical maximum yields of corn are worked out on the basis of actual yield. They were 74.17 q/ha, 52.28 q/ha for N series (200 kg of N/ha) and 71.36 q/ha and 58.33 q/ha for P series (100 kg of P_2O_5/ha) for rainy and winter season respectively.

8. The efficiency factor for soil (c_1) and added nutrient (c) based on Mitscherlic-Bray equation are calculated.

Rainy season :

a) N :- $\log (A-Y) = \log A - 0.00134\ b - 0.00866\ X$.

b) P :- $\log (A-Y) = \log A - 0.0226\ b - 0.00839\ X$.

Winter season :

a) N :- $\log (A-Y) = \log A - 0.00309\ b - 0.01199\ X$.

b) P :- $\log (A-Y) = \log A - 0.0394\ b - 0.0056\ X$.

9. From the ratio of c_1/c it is observed that in the N series, the response of added form of nutrient was found to be more efficient than soil form and vice-versa in P series. The ratio of c_1/c in rainy season was found to be less for both N and P than the winter season indicating more efficiency of soil and fertiliser form in rainy season for increasing grain yield and uptake of N and P by corn.

10. For specific recommendations based on the efficiency factors, the rate of 145.15 kg of N/ha and 57.116 kg of P_2O_5/ha was considered optimum for achieving 96.87 per cent and 87.50 per cent of the theoretical maximum yield respectively in rainy season. While in winter season, the rate of 92.82 kg of N/ha and 20.53 kg of P_2O_5/ha was considered optimum for obtaining 98.34 per cent and 87.50 per cent of the theoretical maximum yield.

11. For obtaining economic optimum yield, the specific fertiliser formulations for N and P based on soil test values, are suggested for the use of routine soil testing laboratories.

The present experimental findings are in close agreement with the modified Mitscherlic-Bray equation, which confirms the validity of the equation.

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* Original not seen.