Effect of Methods and Rates of Lime Application and Different Phosphorus Levels on Growth and Yield of Soyabean (Glycine max (L.) Merrill)

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree

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CERTIFICATION

This thesis entitled "Effect of methods and rates of lime application and different phosphorus levels on growth and yield of soyabean (Glycine max (L.) Merrill)" by Adesoji, Aderemi Gabriel meets the regulations governing the degree of Master of Science (Agronomy) of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation

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This work is affectionately dedicated to people who contributed financially in my pursuit of this higher degree.

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ABSTRACTS

A field experiment was conducted at the Institute for Agricultural Research (IAR) Farm, Ahmadu Bello University, Samaru Zaria, during the 1995 wet season to study the effect of methods and rates of lime application and different phosphorus levels on the growth and yield of soyabean (Glycine max (L.) Merrill). The treatments comprised of two methods of lime application (broadcasting and banding) and three levels each of lime (0,500 and 1000 kg lime/ha) and phosphorus (0, 20 and 40 kg P/ha).

Band method of lime application significantly increased leaf area index, number of primary branches, number of nodules, and Ca concentration in soyabean shoot while broadcast method significantly increased N concentration in soyabean shoot, number of pods per plant, pod yield per plant, total dry matter per plant, total dry matter per hectare and grain yield per hectare. However, the two methods were not significantly different on number of leaves, leaf dry weight, stem dry weight, nodule dry weight, plant height, number of days to 50% flowering, number of days to physiological maturity,100-seed weight, number of seeds per pod, shelling percentage, harvest index and P concentration in soyabean shoot.

Lime levels significantly influenced grain yield, growth and yield components with exceptions of leaf dry weight, number of days to 50% flowering, number of days to physiological maturity, shelling percentage and P, Ca and N concentrations in soyabean shoot. The grain yield was increased with lime application up to

500kg lime/ha but a further increase at 1000kg lime/ha was not significant. The optimum level of lime for maximum grain yield was 780 kg lime/ha.

Phosphorus fertilization significantly increased grain yield, growth and yield components with exception of harvest index which was significantly reduced by P application. The grain yield was increased with increasing P levels up to 40kg P/ha. The optimum rate of phosphorus was 35.4kg P/ha. Application of phosphorus significantly increased P concentration in soyabean shoot, however, phosphorus application had no significant influence on Ca and N concentrations in soyabean shoot.

A significant phosphorus rate and lime level interaction on grain yield showed that the combined application of 40kg P/ha and 1000kg lime/ha gave the highest grain yield while a significant phosphorus rate, lime level and method of lime application interaction showed that the combined application of 40kg P/ha and broadcasting or banding 1000kg lime/ha gave the highest yield. Highly significant and positive correlations were obtained between grain yield and all parameters tested except shelling percentage and harvest index that were not significant.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Origin and Distribution

Soyabean (Glycine max L. Merrill) is a crop which is believed to have come to solve the low protein content of diets of people in humid tropics. Thus, soyabean is an important source of high quality protein in human diets and a leading source of edible oils and fats. This crop is an annual herb belonging to the sub-family papilionoideae of the pea family leguminosae. Soyabean is believed to be a native of Eastern Asia and is one of the oldest cultivated crops (Senewiratne and Appadurai, 1966). The cultigen, Glycine max, is thought to be derived from Glycine ussuriensis and Glycine tomentosa, which grow wild in china (Onwueme and Sinha, 1991).

After so many years of exclusive production in the orient, soyabean was introduced to Europe in the seventeenth century (Onwueme and Sinha, 1991) while the first reference to the cultivation in the United States of America was made in 1904 (Delorit et al., 1974). The earliest record of soyabean cultivation in Africa was by the French in Algeria in the early 1800s (Jackal and Singh, 1989). Ezedinma (1965) reported that the crop was introduced to Nigeria in 1908 while its introduction to Ghana began through official channels in 1909 (Quarshie and Nzo Wah, 1974) and to Cameroon in 1924 (Anon, 1992).

1.2 World Production and Nigeria's Production

The potential uses of soyabeans have made the crop to gain popularity world wide. The estimated annual world total land area and output of soyabean in 1994 were 61.5 million hectares and 136 million metric tonnes, respectively (Anon, 1995). United States of America tops the chart by accounting for 50.3% of total world production while Brazil and China account for 18.3% and 11.8%, respectively. The same report showed that African total area and production were 450,000 hectares and 580,000 metric tonnes, respectively.

Importantly, Nigeria produced 178,000 metric tonnes from 118,000 hectares of land (Anon, 1995). From this, it is clear that Nigeria accounts for 30.7% of total production in Africa. The bulk of soyabean production in Nigeria is centred in Benue State (Nyiakura, 1982) while Kaduna and Niger states also contribute greatly to its production. The crop is now grown in different parts of the country because of its adaptation to the different ecologies, and the high protein and oil contents compared with other legumes. Production is in the hands of small scale farmers.

1.3 Climatic and Soil Requirements

Soyabean has similar climatic and soil requirement with maize (Geus, 1973). It requires a minimum rainfall of 800mm over the 3-4 months growing season and does well at altitudes below 1000metres (Mac Donald and Low, 1984). Soil temperature of 15.5°C

or above favour rapid germination and vigorous seedling growth (Champman and Carter, 1976). Soyabean can succeed on a wide range of soil types but thrives best on sandy or clay loam and alluvial soils of good fertility (Onwueme and Sinha, 1991). Soil pH of 6.0-6.5 is optimal for its production (Chapman and Carter, 1976; Geus 1973).

1.4 Economic Important and Uses of Soyabean.

The composition of soyabean varies with the cultivars,soil and climatic conditions (Purseglove, 1988). The seed protein content ranges from 30 - 50% while the seed oil content ranges from 15-25% (Delorit et al., 1974). Mijindadi (1987) reported that soyabean contains calcium, iron and important vitamins like riboflavin, thiamine and niacin. Also, it is a source of phosphorus (Singh et al., 1989). The seeds are known to contain many essential amino acids except cystine and methione which can be sourced through mixture of soyabean with cereals especially maize (Singh et al., 1989).

1.4.1 Human consumption

Soyabean serves as a good source of food for man. The unripe seeds are cooked and eaten as a vegetable while the dried seeds may be eaten sprouted, fermented, boiled whole or split (Mayhew and Penny, 1988). The seed yields oil which can be used in various forms. The oil is highly digestible, contains high unsaturated fatty acids and contains no cholesterol. It is an

excellent source of energy because of its total digestible nutrient percentage of 92% (Mijindadi, 1987). It can be used in production of "Dawadawa" also called "Dadawa", "Iru" or "Ogiri" which is a traditional condiment (Weingartner, 1989) and in production of soyamilk, "akara" or "Moinmoin" and the flour is used to fortify local starchy foods like bread and biscuits (Onyekwere and Koleoso, 1983). In Nigeria, food products like "soyaogi" which is a maize-soya blend or guinea corn-soya blend (Onyekwere and Koleoso, 1983) and "soya Musa" which consists of extruded soyabean and plantain (Anon, 1992) have been developed for human consumption. Soyabean can also be used in development of "soyagari" which contain 10% protein as compared with 1% from "gari" developed entirely from cassava (Anon, 1992).

1.4.2 Industrial uses

Soyabean oil is used industrially to manufacture several finished goods like margarine, drying oil, salad oil and lotions (Bichi, 1982). The oil is used in making many industrial products like plastics, soap, paints, printing ink, lubricants, celluloid, adhesives, candles and insecticides (Delorit et al., 1974). In addition, the meal and soyabean protein are used in the manufacture of fire-fighting foam, textile sizes, synthetic fibre, water proofing, etc. (Purseglove, 1988).

1.4.3 Livestock feed and other uses.

Soyacake or meal, which is the residue after oil extraction from the seed, is a feedstuff for livestock and is very rich in protein (Purseglove, 1988). Soyabeans produce excellent quality hay when properly handled and are sometimes used in mixture with other crops such as annual grasses for hay, pasture or silage. It is one of the soil improving crops, thus, it helps to increase the nitrogen content of the soil as a result of the presence of nitrogen fixing bacteria in the root nodules. It is also used as a green manure and cover crop (purseglove, 1988).

1.5 Constraints to Soyabean Production

So many constraints have been identified for the low output of soyabean in Nigeria. Soyabean has not become part of many people's diets in Africa because of people reactions that it takes too long to cook, has a bad taste, is poisonous, and cause sterility but the real problem may be lack of familiarity with its processing (Weingartner, 1989). Low output of soyabean can also be attributed to high cost of farming inputs and labour, low yield obtained by farmers as a result of non-application of phosphate fertilizers and lime to acid soils, inadequate number of industries making use of soyabean as raw materials, inadequate markets, and poor market price of the crop.

Other constraints as observed by Singh and Rachie (1989) include poor nodulation, unavailability of inoculum for commercial use, shattering problem, and environmental problems

like pH extremes, Al, Mn, and Fe toxicities and P, K, Mo and S deficiencies in the soil, moisture deficiencies or excesses and temperature extremes. According to them, soyabeans are less susceptible to pests and diseases than indigenous species of Vigna and Phaseolus but there are other problems associated with the requirement and responses of soyabean to high level of management and inputs, the sensitivity of the crop to soil infertility, inadequate moisture and ineffective weed control.

1.6 **Justification and Objectives of the Study**

Low crop production in much of the humid tropics is associated with high soil acidity and /or acute phosphorus deficiencies (Naidu et al., 1990). Acid soil infertility according to Kamprath (1984) is largely due to one or more of Al and /or Mn toxicity, low available P and Ca and/or Mg deficiency. According to Leonard (1986), acid soils have capacity to tie up P by forming insoluble compound with Al, Fe and Mn. However this can be corrected by liming. Liming of medium to strongly acid soils is the very first step toward achieving yield increases in soyabean (Scott and Aldrich, 1970). Similarly, method and rate of liming were observed by Carvalho and Meurer (1980) to increased yield of soyabean. However, little work has been reported on effect of liming on soyabean in savanna zone of Nigeria.

Tropical soils of Africa have been reported Bouyer (1971) to be low in total and available P and according to him, the only exceptions are those soils derived from volcanic parent materials

or those from organic matter. In savanna zones of Nigeria in particular,phosphorus is one of the two major nutrients limiting crop production (Mokwunye, 1979). This justifies the need for application of phosphorus which is essentially important in nodulation, growth, and yield of soyabean. Among three factors studied by Olufajo (1990), lack of P fertilization was found to have the most limiting effect on nodulation, growth and yield of soyabean.

The aim of every soyabean farmer is yield increases with optimum inputs like phosphate fertilizer and lime. It is, therefore, necessary to have well defined rates of these inputs that maximize yield. However the information on interactions between phosphorus and lime on soyabean is very scanty. Also, most of the local farmers do not use these inputs in soyabean production. In the light of the above, this study was designed to achieve the following objectives:

i. To determine how varying rates of lime and phosphorus affect the growth, yield and yield components of soyabean.

ii. To determine the response of soyabean to methods of lime application.

iii. To determine the interaction between phosphorus and lime on soyabean yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effects of Acid Soil on Soyabean

Acid soils are known to significantly affect the availability of plant nutrients which invariably affect the performance of plants. Soil acidity deteriorates the structures of heavy soil. It makes Fe, Al and Mn in the soil more soluble and this makes their concentration in soil to increase until they become toxic to some crops(Cooke, 1982). It makes phosphate less soluble and depresses activities of soil organisms (Cooke, 1982). The most probable reasons for reduced seed yield as indicated by Board and Caldwell (1991) on low pH compared to limed soil was the interference with N fixation and reduced N uptake by plants grown on soil with low pH.

Lee and Chung (1987) reported that acid soils caused significant reductions in stem length, leaf area, dry weight, root activity, nodulation, nitrogen fixation, seed yield and plant P, Ca, Mg, allantion N and total N content of soyabeans. Plant growth, nodulation, yield and protein content of soyabean decreased as pH decreased (Lee and Lee, 1986). Lime programme on acid soils is needed in order to maintain production efficiency, increase yield per hectare and produce better quality crops (Jones, 1987).

2.2 Lime

Liming of acid soil is very important because it neutralizes soil acidity by raising the soil pH, supplying calcium and

magnessium, hastening the decay of organic matter and the availability of other nutrients, and increasing the availability of residual and applied phosphorus (Jones, 1987). Liming increases nitrogen fixation and crop yields, and improves physical properties of soils (Jones, 1987). Liming of acid soils improves Ca and Mg status, and reduces Al and Mn availability of soil (March and Grove, 1992).

Liming of acid soils is generally believed to stimulate nodulation and nitrogen fixation of leguminous crops (Weinmamn, 1959). Over liming, however,can lead to raising of pH above 6.5 which may cause micro nutrient deficiencies except molybdenum and may also cause reduction in phosphorus availability because it may form insoluble compound with calcium and magnessium (Leonard, 1986).

2.2.1 **Effect of lime on the growth of soyabean**

Soyabeans have been reported to perform poorly on acid soil because their particular type of N fixing Rhizobia have little tolerance for pH below 6.0 (Leonard, 1986). Soyabeans respond favourably to application of lime if the pH is below 6.0 (Delorit et al., 1974). Significant growth responses to lime application were observed by Mangel and Kramprath (1978) and Noble et al. (1984) while Kueneman (1982) obtained a slight improvement in growth of soyabean. However, excess liming has shown to reduce plant growth (Amarasiri and Olsen, 1973; Juo and Uzu, 1977).

An increase in root length of soyabean was obtained with increasing lime rates (March and Grove, 1992). Liming at the rate

of 3t/ha was observed by Martini and Multer (1989) to improve nutrient availability and stimulate the development of fine root system whereas, higher liming rates inhibited development of root system and reduced the availability of trace elements. Likewise, lime has been reported by Ismunadji and Makarin (1989) to increase plant dry weight, plant height and to promote root development of soyabean. Similarly, application of lime was observed to significantly increase dry matter yield of soyabean (Ramos et al., 1989).

2.2.2 Effect of lime on nodulation of soyabean

Calcium which is normally added to soil in form of lime, plays a vital role in the rhizobium infection of plant root and in the development of nodules (Loneragam and Dowling, 1958). Lime application was observed by Ismunadji and Makarin (1989) to promote nodule formation. Likewise, Pal et al. (1983) reported an increase in soyabean nodulation after liming while Danso (1988) observed that lime pelleting of inoculated soyabean seeds caused increased in nodulation by about 13 times than of the direct seed inoculation only treatment. However, application of lime at high rate of 4 or 6t/ha was observed by Samarao et al. (1986) to reduce nodule dry weight.

2.2.3 Effect of lime on yield and yield components of soyabean

Soyabean cannot produce high yields on highly acidic soils (Leng and Whigham, 1974). Raij et al. (1977) reported that lime

application had a positive effect on soyabean yield and increased soil pH from 4.7 to 6.3. The maximum yield was attained at pH 6.0. Similarly, in experiment conducted by Samonte (1985) on lime acidic soils,optimum yields of soyabean were obtained at pH 6.1-6.4.

Jones (1987) stated that the consensus of soyabean production specialists on acid soils is that yield increases from proper liming may range from 202 to 538kg/ha. Prasad (1992) indicated that lime significantly increased soyabean yield to a certain level (0.8t/ha) after which larger doses were found to be non beneficial. In a like manner, yield increases of soyabean have also been observed with lime application (Rhodes and Nangju, 1979; Mascarenhas et al., 1982; Samarao et al., 1986). Apart from yield, seed quality assessed by germination percentage and 100-seed weight were observed by Forbes et al. (1986) to increase after lime application. Similarly, application of lime increased seed size of soyabean between 12 and 20% (Mascarenhas et al., 1982).

2.2.4 Effect of method of lime application on soyabean.

Lime reaction is generally limited to the depth of incorporation (March and Grove 1992). However, in an experiment conducted by Tanner (1983) on depth of incorporation of lime and P, he found that the depth of incorporation had no effect on the efficiency of lime or P utilization as shown by soyabean responses in early growth, P content in leaves, seeds or seed yield.

Deep band placement of dry lime had been observed to increase soyabean yields and gave economic returns which ofset the increased cost of treatment (Tupper et al., 1987). Coating of inoculated seed of soyabean with dolomite favoured nodulation and increased yields compared with uncoated seeds. These yields and nodulation were similar to those achieved with application and incorporation of 2t dolomite/ha (Samson et al., 1986). Nakayama et al. (1984 compared broadcast and row applications of lime and found that broadcast application increased grain yield and improved chemical status of the soil.

In the study on effect of broadcast and band placement of limestone on soyabean, Carvalho and Meurer (1980) observed that lime treatment significantly increased soyabean yields except at lowest rate of band applications. They reported that broadcast gave much higher yields than band placement and increased the soil pH in ploughed layer while band application did not increase soil pH. However, lime broadcasting reduced the concentration of K, Mg, Mn and Zn in soyabean leaves.

2.2.5 Effects of lime on nutrient contents and concentrations of soyabean

Lime application has been shown to have considerable influence on nutrient contents and concentrations of soyabean. Samonte (1985) reported that an improvement in the N status of soyabean was achieved through application of lime which was reflected in higher concentration of N in the tissues, greater N

uptake and grain N content. Likewise, application of lime has been shown to increase the uptake of N,P,K, Ca and Mg of the soyabean crop (Bishnoi et al., 1988). In an experiment conducted by Gupta (1989) on several crops including soyabean, liming was reported to increase the concentration of phosphorus and calcium in crop grains while uptakes of P, Ca and K were increased.

Noble et al. (1984) reported significant reduction in soyabean plant Al, Zn, Fe, Mn and Mg with increasing levels of lime. Similarly, Quaggio et al. (1982) reported that Mn concentration of the soil and leaves decreased with application of lime while Patiram et al. (1990) observed a decrease in Al content of soyabean after lime application. In a similar manner, lime application was observed Gupta (1989) to reduce the potassium concentration of soyabean grain.

2.3 Phosphorus

All living things need phosphorus and every living cell cannot do without it. Jones (1987) stated that phosphorus plays a role in these following processes in plants: the breakdown of carbohydrate for energy release, cell division, transfering of inherited characteristics, stimulation of early root growth and development, hastening maturity of plant, fruiting and seed production, and energy transformation. DeMooy et al. (1973) indicated that phosphorus plays a role in the formation of high energy molecules, synthesis of cell constituents, and in the formation and translocation of carbohydrate, fatty acids and

nucleo proteins.

The deficiency of the phosphorus retards growth and delays maturity. According to Leonard (1986), phosphorus deficiency in pulses and pasture legumes causes poor vigour in the plants which have few side branches, the upper leaves to remain small and become dark green and, the retardation of flowering and maturity.

2.3.1 Effect of phosphorus on the growth of soyabean

Phosphorus is necessary for soyabean at all growth stages (Cartter and Hartwig, 1963). Absorption of phosphorus by soyabean from fertilizer is generally high and continues to the end of the season (Norman, 1978) and the period of greater demand of phosphorus by soyabean starts before the beginning of pod formation and continues until about ten days before the seeds are fully developed (Scott and Aldrich, 1970). As reported by Nangju (1975) soyabean needs 20-40kg P/ha for optimum growth.

In an experiment conducted on 4 different soils, P application increased shoot weight, plant height, number of trifoliate leaves and leaf area of soyabean in all the 4 soils and increased root weight in 3 soils (Howard, 1988). Similarly, Chiezey (1990) showed that number of leaves per plant, number of branches, plant height, leaf area index and dry matter of soyabean were increased following phosphorus fertilization. Nevertheless, on findings of Chesney (1973), soyabean that received insufficient supply of phosphorus had a small stature and matured about two weeks earlier than those that received

sufficient supply of phosphorus.

2.3.2 Effect of phosphorus on nodulation of soyabean

Application of phosphorus causes increases in number, weight and size of nodule (DeMooy and Pesek, 1966). Nodules were indicated by Graham and Rosas (1979) to form a strong sink for P. Tomar et al. (1991) reported that applied P increased soyabean nodule number per plant from 26 to 49-51, while Howard (1988) observed that number of nodules per pot in two soils were increased by P application out of 4 soils experimented on. Similarly, Sabesan and Sathananda (1986) observed that application of phosphorus increased soyabean nodulation and N fixation, while Olufajo (1990) observed that lack of application of phosphorus highly reduced soyabean nodulation.

2.3.3 Effect of phosphorus on the yield and yield components of soyabean

Uninoculated soyabeans in Nigerian savanna have been reported by Pal et al. (1989) to require 24-39kg P/ha for maximum yield while Lawrence et al. (1976) found that 43.6kg P/ha caused maximum yield of soyabean in Lousina, U.S.A. Yield increases as a result of phosphorus application on soyabean have been widely reported by researchers (Chesney, 1973; Trabulsi, 1985; Chiezey, 1990; Jayapaul and Ganesaraja, 1990; Naidu and Pillai, 1991). However, application of high levels of phosphatic fertilizer may have little or no effect on yield but modest levels of

application will maintain productivity (Smart, 1976).

Apart from yield, phosphorus application also affects yield components. Jayapaul and Genesaraja (1990) noted that phosphorus fertilization increased the number of pods per plant and seeds per pod, and 100-seed weight, while Syafruddin et al. (1991) observed that harvest index of soyabean was increased by P application. Similarly, Chiezey (1990) reported that soyabean retained more pods per plant, heavier pod per plant and heavier seeds and higher grain yield per plant and per unit area after application of 26kg P/ha but harvest index was not significantly affected by phosphorus level. This he attributed to the fact that application of phosphorus increased both the grain yield and total dry matter by the same magnitude.

2.3.4 Effect of phosphorus on nutrient contents and concentrations of soyabean

Phosphorus has been found not only to increase growth, nodulation, yield and yield components of soyabean, but also to improve the crop quality. Nimje and Seth (1988) observed increases in N, P, and K contents in plants and seeds of soyabean and N,P and K uptake at flowering and at harvest after phosphorus fertilization, while Naidu and Pillai (1991) reported increases in N, P, K, S, Ca and Mg in seeds of soyabean as a result of P application. However, Souza et al. (1984) reported that phosphorus had no effect on N, K, Fe, Mn, Zn and Cu concentrations in leaves of soyabean.

Addition of phosphorus fertilizer has been shown by Fazal and Sisodia (1989) to increase oil content of soyabean while Jayapaul and Ganesaraja (1990) observed an increase in protein content of soyabean after P application. However, Chiezey (1990) reported that oil and crude protein of soyabean seed were not significantly affected by phosphorus levels probably because oil and protein contents of the seed are genetically determined.

2.4 Phosphorus and Lime Interaction on Soyabean

There is not much information on interaction between phosphorus and lime on soyabean. Lime and phosphorus interaction has been attributed to the effect of lime on improving root exploitation of available P in the soil (Friesen et al., 1980). Similarly, Haynes (1984) reported that lime and phosphorus applications tend to compensate for one another in terms of plant response. A lower level of P with liming has been observed to be good as higher level without liming on soyabean (Kalia et al., 1984). In a study conducted by Ferrereira et al. (1979) on soyabean, highest yield was obtained by addition of 1.2t limestone and 267.5kg P/ha. Similarly, highest yield of 3.58t /ha of soyabean was obtained by Scherer et al. (1979) after application of 44kg P/ha as triple superphosphate + hyperphosphate, and lime. Increasing limestone rates from 0 up to 7t limestone/ha in the presence of 26.4kg P/ha caused an increase in soyabean grain yield in the last two years of 3 years experiments conducted by Mascarenhas et al. (1988).

In contrast, some workers have reported non-significant and declined yield from lime and phosphorus interaction in soyabean. Bataglia et al. (1984) reported that the presence of lime brought no marked effect of P on yield or P uptake. Similarly, Hanson and Sebaugh (1982) reported that there was no significant yield increase with lime when adequate P was supplied to soil grown to soyabean. Noble et al. (1987) observed significant yield declines in soyabean cultivar "Forest" at higher levels of lime and phosphorus.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Experimental Site

A field experiment was conducted during the rainy season of 1995 at the Agricultural Research Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru Zaria (11° 11'N and 7° 38' E, 650m above sea level) in the northern guinea savanna ecological zone to test the response of soyabean to methods and rates of lime application and different levels of phosphorus.

The soil of the experiment site was loam. Prior to planting, soil samples were taken to a depth of 30cm and were analysed for physical and chemical properties, details of which are shown in Appendix 1 while details of meteorological records during the period of the experiment are shown in Appendix 2.

3.2 Treatments

Treatments consisted of factorial combinations of two methods of lime application (broadcasting and banding), three rates of lime (0,500 and 1000kg calcite/ha) and three levels of phosphorus (0, 20 and 40kg P/ha). Single superphosphate (SSP) was used as a source of phosphorus (P). In all, there were eighteen treatment combinations.

3.3 Experimental Design and Plot Size

The experiment was laid out in a randomized complete block design (RCBD) with three replications.

The gross plot size was $27m^2$ (6m x 4.5m) while the net plot size was $15m^2$ (5m x 3m). The total experimental area was $1935m^2$ or 0.1935 ha (60m x32.25m). The sowing was done manually on 75 cm ridge.

3.4 Determination of Soil Nutrient Status

Soil samples were collected from randomly selected spots on the field. Samples were taken to a depth of 30cm after ploughing and harrowing but before ridging, fertilizer and lime application, and analysed for physico-chemical properties (Appendix 1).

3.4.1 Particle size analysis

Particle size distribution was analysed by the hydrometer method (Bouyoucos, 1951) and textural class was determined by using the soil textural triangle (Anon, 1960).

3.4.2 Soil pH

Soil pH was determined in water and O.O1M $Cacl_2$, by using a soil solution ratio of 1:2.5 by means of a Philip analogue pH meter.

3.4.3 Organic carbon

The organic carbon content of the soil was determined by the wet oxidation method of Walkley - Black described by Allison (1965).

3.4.4 **Total nitrogen**

Total nitrogen content of the soil was determined by the macro Kjeldhal procedure (Bremner, 1965; Anon, 1975).

3.4.5 **Available phosphorus**

Available phosphorus was determined by the method described by Trough (1930). The extracted phosphate was determined by the molybdate blue colour method (Bray and Kurtz, 1945; Murphy and Riley, 1962).

3.4.6 **Exchangeable bases**

The exchangeable bases, calcium (Ca), magnessium (Mg), potassium (K) and sodium (Na) were extracted using 1N acetate (pH 7.0). Extracted K and Na were determined by flame emission spectrophotometry while Ca and Mg were determined using atomic absorption spectrophotometry.

3.4.7 **Cation exchange capacity**

Cation exchange was determined by ammonium saturation method. This was done by using 1N ammonium acetate (pH 7.0) saturation followed the displacement of the absorbed ammonia (Chapman, 1965).

3.5 **Cultural Practices**

3.5.1 **Land preparation**

The experimental area was disc-ploughed and harrowed twice to a fine tilth. This operation was followed by ridging at 75cm

apart. The experimental field was marked into three replicates. The plots were separated by 0.75m unplanted discards, while the replicates were separated by 1.5m unplanted discards.

3.5.2 Planting

Planting was done on the 4th July, 1995. The seeds were sown at spacing of 4.4cm on the ridges 75cm apart to achieve a plant population of 300,000 plants/ha.

3.5.3 Planting material

The soyabean variety, Samsoy 2, was used for the experiment. Samsoy 2 is a short and stout variety. It is determinate in growth habit, has large yellow seeds which are in clustered pods. It is relatively resistant to shattering and is of medium maturity (112-118 days).

3.5.4 Lime and fertilizer application

The three rates of calcite ($CaCo_2$) were applied by broadcasting and banding. The compositions of the lime are presented in Appendix 1. The broadcast application was done by spreading the calcite uniformly on the soil and it was raked into the soil while on band application, the calcite was band applied to a row at about 7cm away from the plants. The three levels of phosphorus were applied by banding at 7cm away from the plants. All the applications were done at planting.

3.5.5 **Weed control**

Weed control was achieved manually by hoeing. This was done thrice, the first weeding at 3 weeks after sowing (WAS), the second weeding at 6 weeks after sowing, and the third at 10 weeks after sowing.

3.5.6 **Disease and pest**

No serious disease and pest attack was observed on the plants throughout the growth. They maintained a healthy appearance.

3.5.7 **Harvesting**

Harvesting was done when the leaves of the soyabean plants had changed to yellow and later dried off in the field. The net plot ($15m^2$) was used for the harvest. The harvested soyabean plants per plot were packed together in each plot to dry thoroughly for two weeks before threshing.

3.5.8 **Threshing**

The threshing was done manually. The clean seeds separated from chaff after winnowing from each plot were used to determine the yield.

3.6 **Observation.**

Beginning from the fourth week after sowing (WAS) and at two weekly interval up to twelfth week after sowing, five plant

samples were harvested from each plot to determine the pre-harvest parameters while at harvest, ten plant samples were used to determine post harvest parameters with exception of harvest index, total dry matter per hectare and grain yield per hectare.

3.6.1 Number of leaves per plant

The number of leaves per plant was obtained by counting total number of leaves from five plant samples and the average number of leaves was recorded.

3.6.2 Number of primary branches per plant

This was obtained by counting the total number primary branches from five plant samples and the average number of branches was obtained.

3.6.3 Number of nodules per plant

This was determined by carefully removing five plants with the aid of a garden fork and the nodules carefully detached from the roots and cleaned of soil particles. The nodules were counted and the mean number of the nodules recorded.

3.6.4 Number of days to 50% flowering

Number of days to 50% flowering was recorded for each plot as the number of days from sowing to when half of the plants had produced first flower.

3.6.5 Plant height

The height of the five sampled plants were measured in cm from ground level to the top of the main stem, using a metre rule.

3.6.6 Leaf dry weight per plant

The leaf dry weight per plant was determined by weighing oven dried leaves at 70°C for 72 hours from five plants sampled using a sensitive Mettler scale model P 1210 and the mean dry weight of leaves recorded

3.6.7 Stem dry weight per plant

This was determined by weighing oven dried stems at 70°C for 72 hours of the five plants by using a Mettler scale model P 1210 and the mean dry weight of the stems was recorded.

3.6.8 Nodule dry weight per plant

The dry weight of the nodules was determined by weighing oven dried nodules at 70°C for 72 hours of the five sampled plants using a Mettler scale model AE 50 and the mean weight of the nodules was recorded.

3.6.9 Leaf area index (LAI)

Leaf area index was calculated by dividing the total leaf area (A) of the leaves by the area of the ground (P) covered by the leaves (Watson, 1947 and 1952).

$$LAI = \frac{A}{P}, \quad A = \text{Total leaf area of the leaf } (cm^2).$$

$$P = \text{ground area } (cm^2).$$

3.6.10 **Number of days to physiological maturity.**

This was determined by noting the number of days from sowing to when the pods or 50% of the leaves of the plant in each net plot had turned to yellow (Fehr, et al., 1971).

3.6.11 **Number of pods per plant**

Number of pods per plant was determined by the dividing the total number of pods produced by ten plant samples by ten (number of plants).

3.6.12. **Pod yield per plant**

This was determined by detaching pods of the ten plant samples by hands and weighed. The mean was recorded.

3.6.13 **Number of seeds per pod**

Number of seeds per pod was determined by dividing the total number of seeds from ten plants by number of pods harvested from the plants.

3.6.14 **100 - seed weight (g)**

Hundred seeds from each net plot were randomly selected and weighed with Mettler P 1210 weighing balance.

3.6.15 Shelling percentage

The shelling percentage was determined at harvest by dividing the weight of the shelled grains or seeds by the weight of the unshelled pods obtained from the ten plant samples and the result was multiplied by 100 to convert it to percentage.

3.6.16 Total dry matter per plant

Total dry matter per plant was determined at harvest by weighing oven dried ten plant samples (at 70°C for 72 hours). The mean was recorded.

3.6.17 Total dry matter per hectare

Total dry matter per hectare was determined at harvest by cutting the entire plants in each net plot from ground level and allowed to dry for two weeks and weighed by using Salter scale model 250, and the value obtained was multiplied by 666.67 to convert it to kilogrammes per hectare.

3.6.18 Grain yield (kg/ha)

Total grain yield was determined at harvest by threshing the entire plants harvested from net plot. The grain yield was then determined by weighing the threshed grains using a Mettler scale model P 1210 and the value obtained was multiplied by 666.67 to convert the grain yield to Kilogrammes per hectare.

3.6.19 **Harvest index**

The ratio of seed to the total dry matter was calculated from the equation below:

$$\text{Harvest index} = \frac{\text{Grain Yield from Xkg TDM}}{\text{xkg of TDM}} \times \frac{100}{1}$$

TDM = Total Dry Matter per hectare.

3.6.20 **Plant nutrient analysis**

Plant samples (shoot) were taken at 8 WAS to determine the N, P and Ca concentrations. Oven dried plant samples (shoot) from each plot were properly ground in a mill to fine powder for analysis. Total plant nitrogen was determined by the macro-kjeldhal procedure (Bremner, 1965; Anon, 1975). Total plant phosphorus was determined by the molybdate blue colour method (Bray and Kurtz, 1945; Murphy and Riley, 1962). Plant calcium content was determined by using atomic absorption spectrophotometry.

3.7 **Data Analysis**

The data collected were subjected to analysis of variance (Snedecor and Cochran, 1967). Significant differences among treatment means were compared using the Duncan Multiple Range Test (DMRT) as described by Duncan (1955). Correlation and regression analysis were also carried out.

3.8 **Meteorological Data**

Rainfall, temperature, sunshine and relative humidity data covering the period of the experiment were obtained from the IAR meteorological station, Samaru (Appendix 2).

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of Methods of Lime Application and Rates of Lime and Phosphorus on Growth of Soyabean.

4.1.1 Leaf area index.

Maximum leaf area index (LAI) was attained at 10WAS and subsequently declined (Fig.1). Methods of lime application significantly influenced leaf area index at all growth stages except at 4WAS. At 10WAS, banding of lime significantly increased the LAI by 11% over broadcasting.

Application of lime significantly influenced LAI at all sampling stages (Fig. 1). At 10WAS, increasing lime level from 0 to 500kg lime/ha resulted in 11.7% increase in LAI, but a further increase of lime level from 500 to 1000kg lime/ha had no significant effect.

Phosphorus application significantly increased LAI at all growth stages (Fig. 1). At 10WAS, increasing P level from 0 to 20kg P /ha resulted in 40.6% increase in LAI and 16.1% increase was observed by increasing P level from 20 to 40kg/ha.

Significant interactions observed on LAI were:

a) Phosphorus rate x method of lime application; where the highest LAI was recorded with combination of 40kg P/ha and band method of liming (Table 1).

b) Lime level x method of lime application; the highest LAI was observed with the banding of 500 or 1000kg lime/ha (Table 2).

c) Phosphorus rate x lime level x method of lime

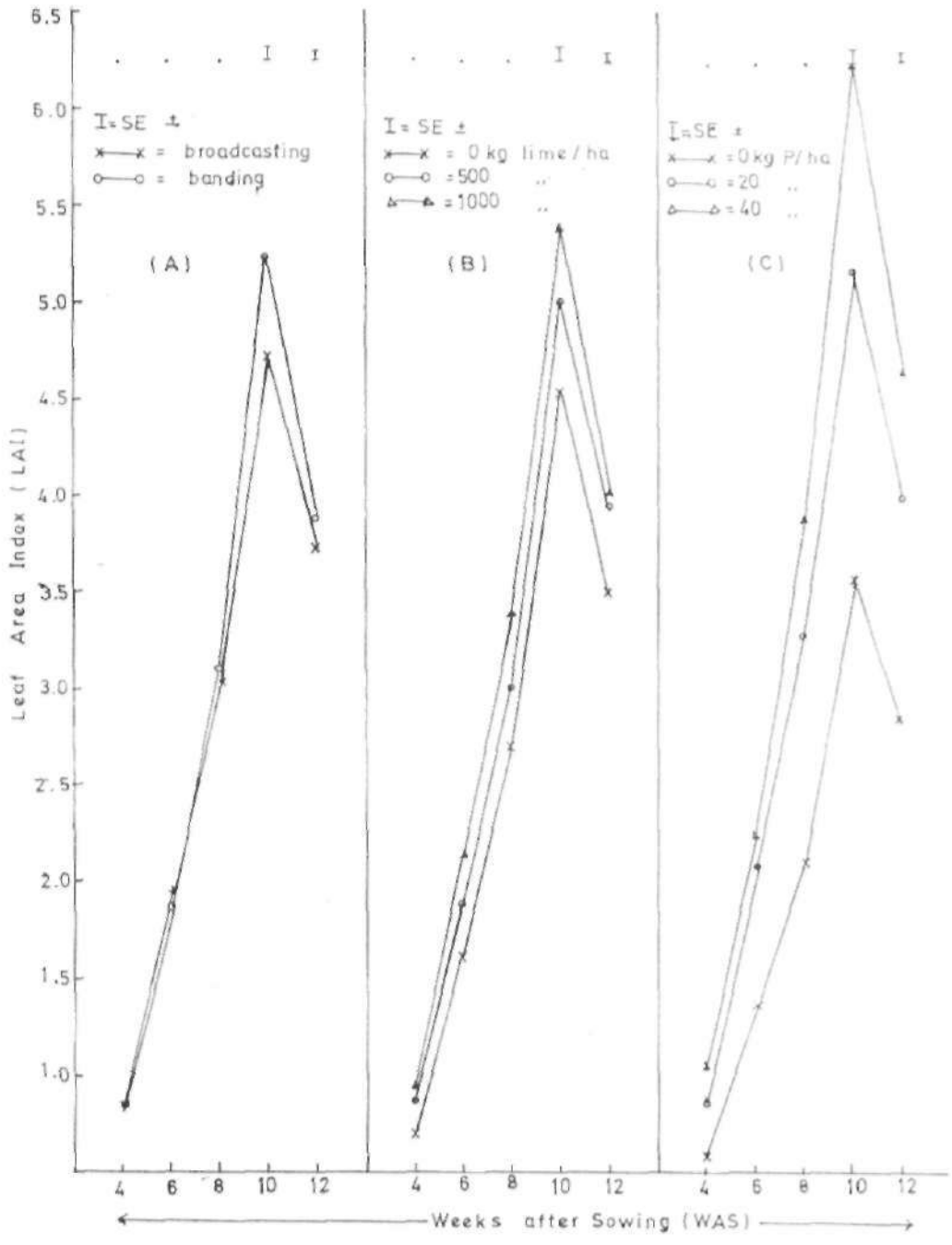


Fig. 1: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on leaf area index of soyabean at different weeks after sowing.

Table 1: Interaction between phosphorus rate and method of lime application on leaf area index (LAI) of soyabean at 10WAS at Samaru, 1995.

Treatments	Lime application methods	
	Broadcasting	Banding
Phosphorus (kg P/ha)		
0	3.53d	3.65d
20	4.60c	5.76b
40	6.08ab	6.37a
SE±	0.12	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 2: Interaction between lime level and method of lime application on leaf area index (LAI) of soyabean at 10WAS at Samaru, 1995.

Treatments	Lime application methods	
	Broadcasting	Banding
Lime (kg/ha)		
0	4.60c	4.53c
500	4.52c	5.55a
1000	5.08b	5.70a
SE±	0.12	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

application; the highest LAI was produced with a combination of 40kg P/ha and banding of 500kg lime/ha (Table 3).

4.1.2 Number of leaves per plant.

Maximum number of leaves per plant was attained at 12WAS (Fig 2). The number of leaves was significantly affected by methods of liming at 4WAS only. At 12WAS, there was no significant difference between the two methods of liming on number of leaves.

Lime application significantly increased number of leaves at all growth stages (Fig. 2). At 12WAS, increasing lime level from 0 to 500kg lime/ha had no significant effect on number of leaves but a further increase of lime level from 500 to 1000kg lime/ha significantly increased leaf number by 4.2 %.

Application of phosphorus significantly increased number of leaves at all sampling dates (Fig.2). Application of 20 and 40kg P/ha increased leaf number at 12WAS by 18.7% and 28.4%, respectively, compared with the zero P treatment.

4.1.3 Leaf dry weight (g) per plant

Maximum leaf dry weight per plant was attained at 12WAS (Fig.3). Methods of lime application had a significant effect on leaf dry weight at 8 and 10WAS only. At 12WAS, methods of liming had no significant effect on leaf dry weight.

Table 3: Interaction among phosphorus rate, lime level and method of lime application on leaf area index (LAI) of soyabean at 10WAS at Samaru, 1995.

Lime application methods	Lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
	0	2.91m	4.65ghi	6.26bc
Broadcasting	500	3.51klm	4.29hij	5.77cd
	1000	4.16ijk	4.88fgh	6.21bc
	0	3.15lm	5.02efg	5.40def
Banding	500	4.04ijk	5.62cde	6.99a
	1000	3.75jkl	6.64ab	6.73ab
		SE±	0.20	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

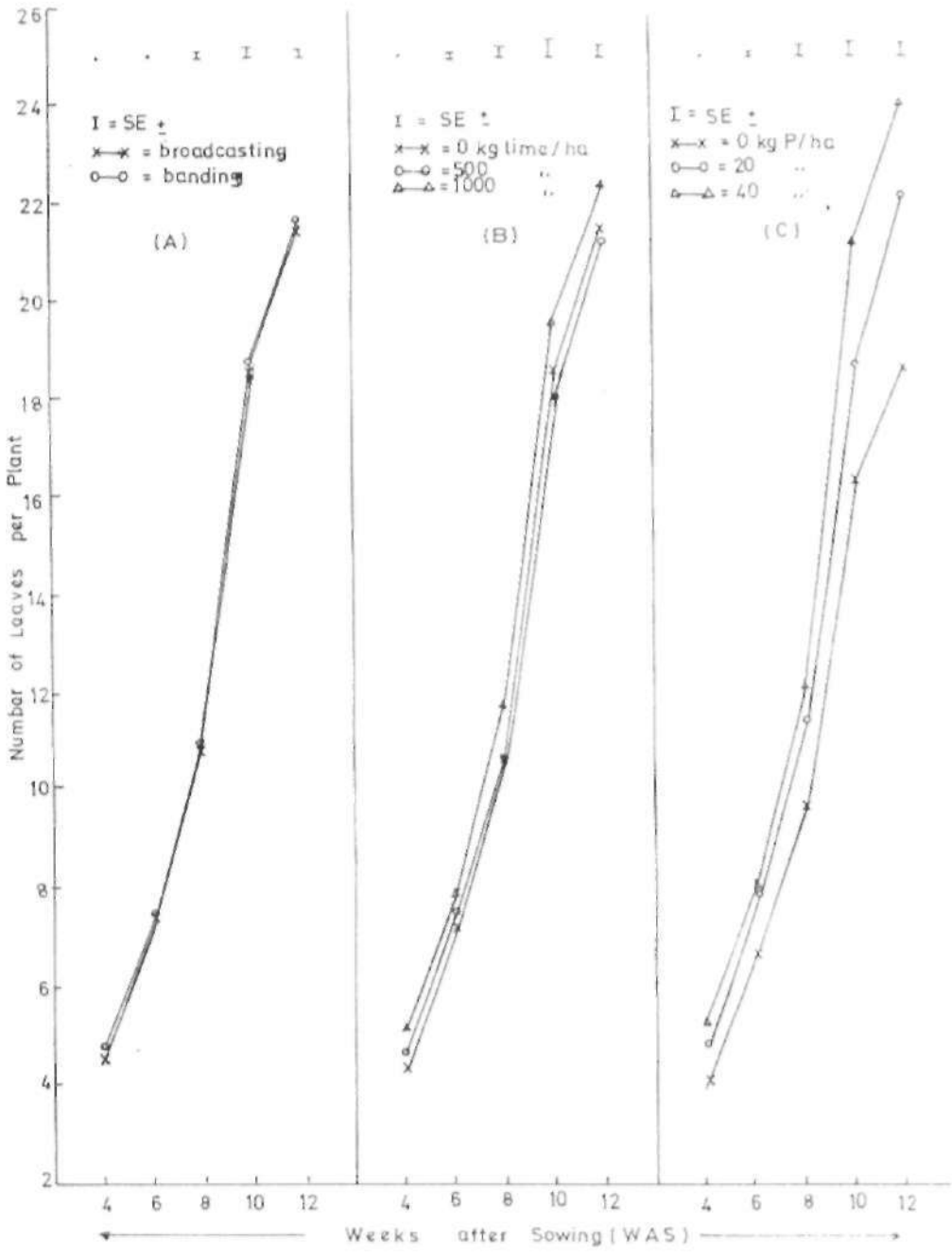


Fig. 2: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on number of leaves per plant of soyabean at different weeks after sowing.

Application of lime significantly increased leaf dry weight at 4, 6 and 8WAS (Fig. 3). At maximum leaf dry weight, lime application had no significant effect on leaf dry weight.

Phosphorus application significantly increased leaf dry at all growth stages (Fig. 3). At maximum leaf dry weight, application of 20 and 40 kg P/ha increased leaf dry weight by 70.9% and 87.2%, respectively, compared with the no P treatment.

4.1.4 Stem dry weight (g) per plant

Maximum stem dry weight per plant was attained at 12WAS (Fig.4) Methods of lime application significantly influenced stem dry weight at 4 and 10WAS only. At maximum stem dry weight, there was no significant differences between the two methods of liming on stem dry weight.

Lime application significantly increased stem dry weight at all sampling periods (Fig. 4). Application of 500 and 1000kg lime/ha increased stem dry weight at 12WAS by 5.8% and 7.8%, respectively, over the zero lime treatment.

Application of phosphorus significantly influenced stem dry weight at all growth stages (Fig.4). At 12WAS, stem dry weight was significantly increased by 74.2% and 106.7% with application of 20 and 40kg P/ha, respectively, over the no P treatment.

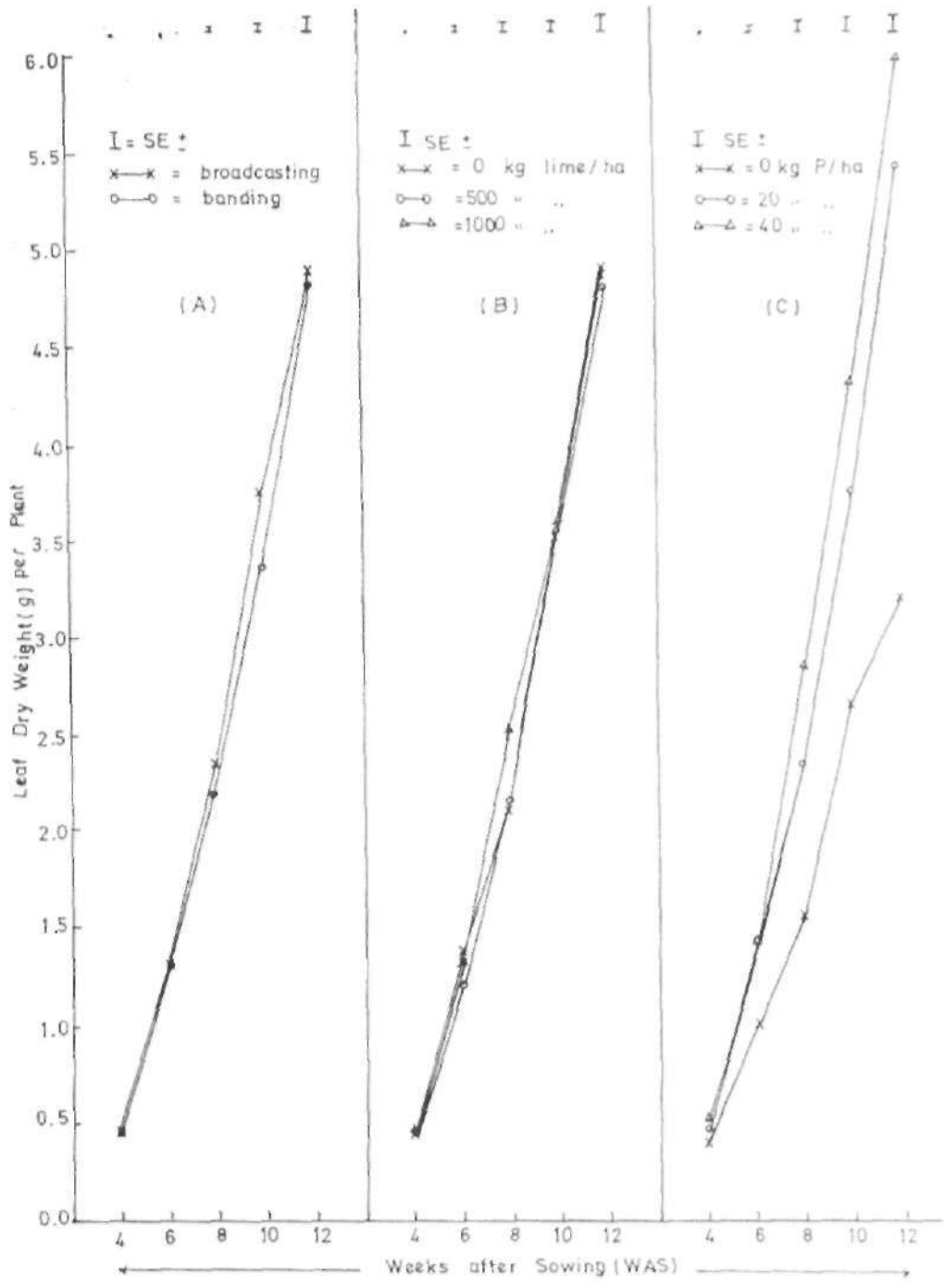


Fig. 3: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on leaf dry weight (g) per plant of soyabean at different weeks after sowing.

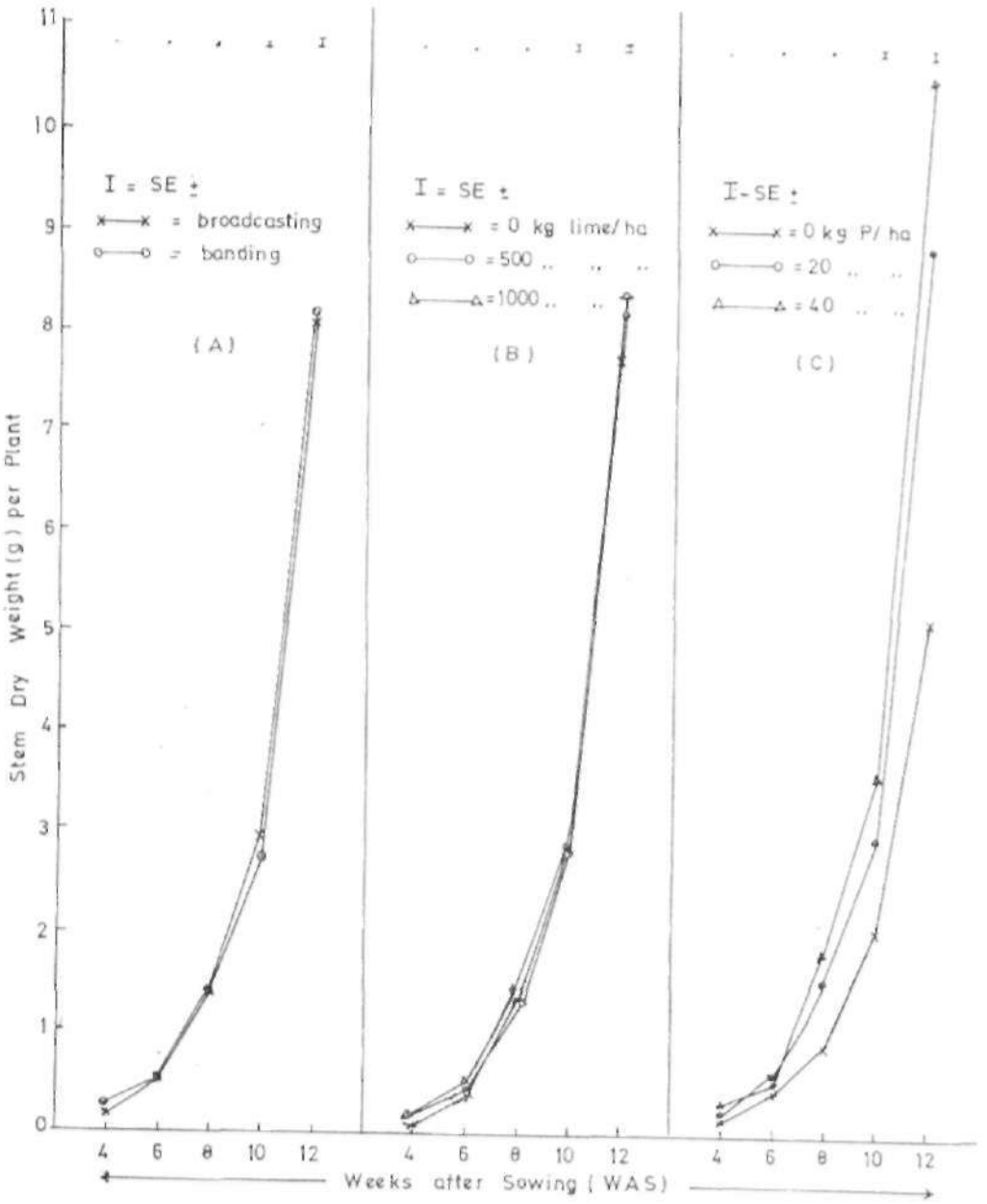


Fig. 4: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on stem dry weight (g) per plant of soyabean at different weeks after sowing.

4.1.5 Number of primary branches per plant

Maximum number of primary branches was attained at 12WAS (Fig. 5). Methods of lime application had a significant effect on number of primary branches at 4 and 12WAS only. At 12WAS, banding of lime significantly increased number of primary branches by 3.2% over broadcasting.

Number of primary branches was significantly affected by liming at all growth stages (Fig. 5). At 12WAS, application of 500kg lime/ha significantly increased number of primary branches by 5.8%, but a further increase of lime level from 500 to 1000kg lime/ha had no significant effect on the branches.

Phosphorus application significantly influenced number of primary branches at all sampling periods (Fig. 5). At 12 WAS, application of 20kg P/ha significantly increased number of primary branches by 14.8%, but a further increase of P level from 20 to 40kg P/ha had no significant effect on the number of primary branches.

4.1.6 Number of nodules per plant

Maximum number of nodules per plant was attained at 12WAS (Fig.6). Number of nodules was significantly affected by methods of liming at 6, 8 and 12 WAS. At 12WAS, banding of lime significantly increased number of nodules by 3.6% over broadcasting.

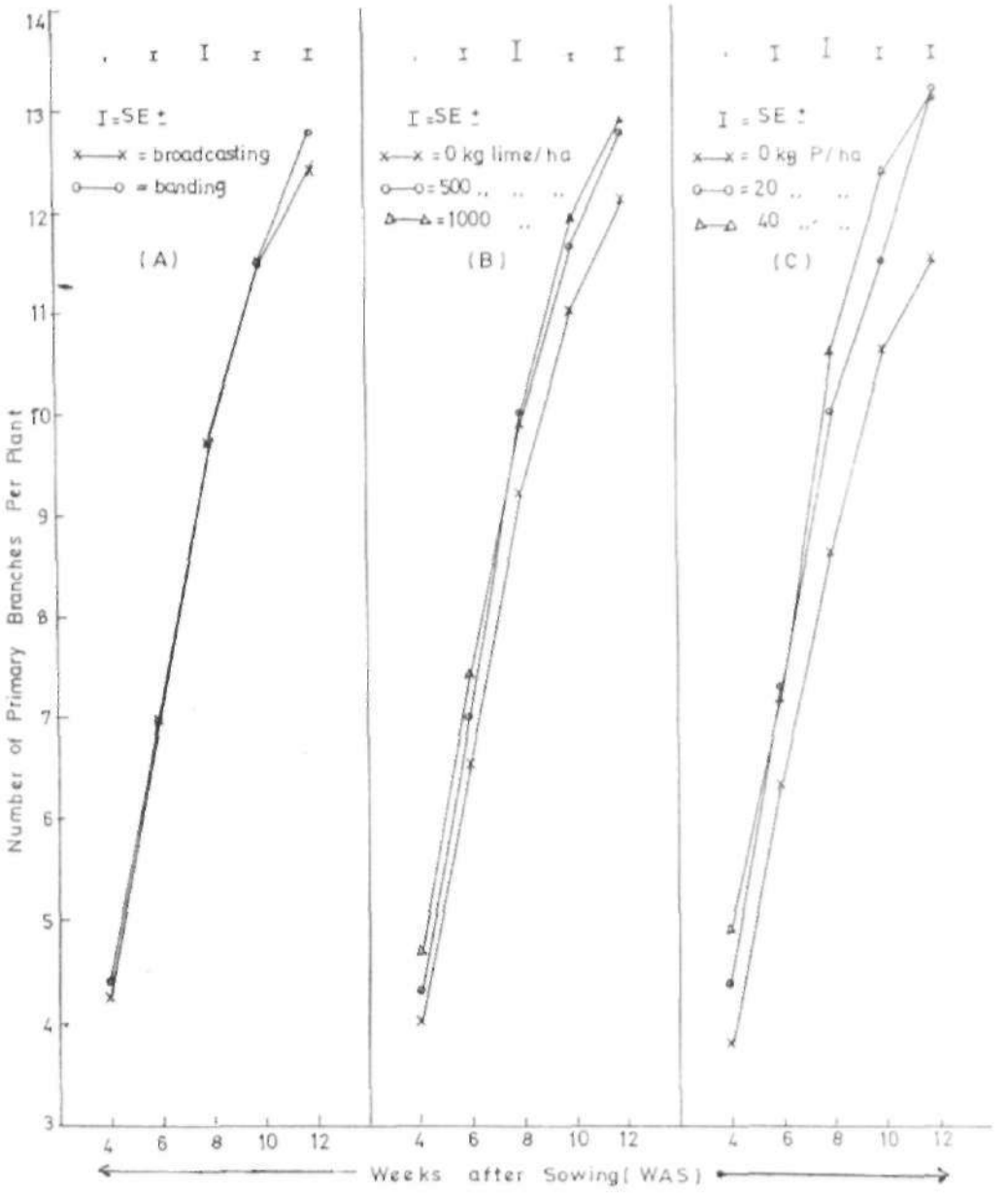


Fig. 5: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on number of primary branches per plant of soyabean at different weeks after sowing.

Lime application significantly increased number of nodules at all sampling periods (Fig. 6). At 12WAS, application of 500 and 1000kg lime/ha increased number of nodules by 46.1% and 79.2%, respectively, compared with the zero lime treatment.

Application of phosphorus significantly increased number of nodules at all growth stages (Fig. 6). At maximum number of nodules, application of 20 and 40kg P/ha increased number of nodules by 56.4% and 83.7%, respectively, over the no P treatment.

The following interactions were significant:

a) Phosphorus rate x lime level; application of 20kg P/ha and 1000 kg lime/ha produced the highest number of nodules (Table 4)

b) Phosphorus rate x method of lime application; the highest number of nodules was observed with a combination of 40kg P/ha and band method of liming (Table 5).

c) Lime level x method of lime application; the highest nodule number was obtained with broadcasting or banding of 1000kg lime/ha (Table 6).

d) Phosphorus rate x lime level x method of lime application; the highest number of nodules was produced with a combination of 20kg P/ha and broadcasting of 1000kg lime/ha (Table 7).

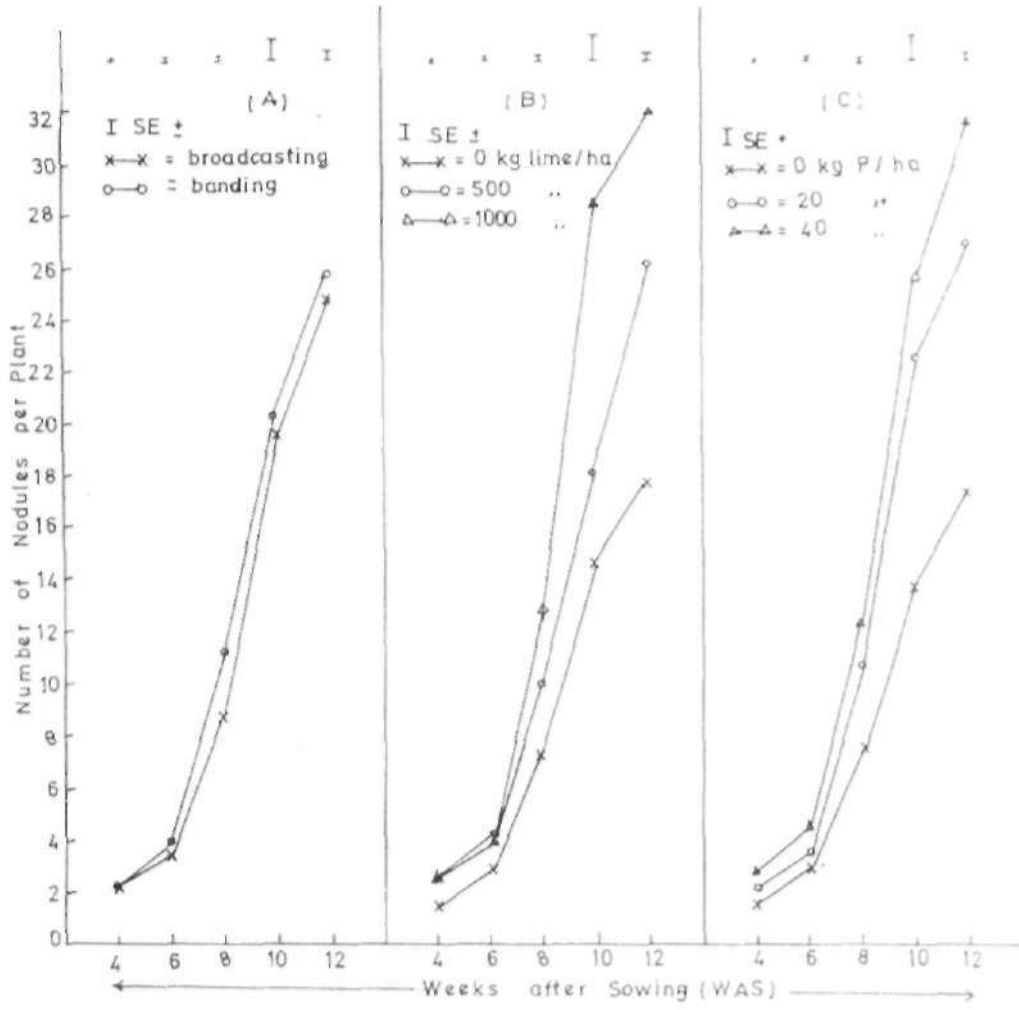


Fig. 6: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on number of nodules per plant of soyabean at different weeks after sowing.

Table 4: Interaction between rates of phosphorus and lime on number of nodules per plant of soyabean at 12WAS at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	11.4f	21.7c	18.4e
20	19.7de	20.7cd	40.2a
40	22.2c	35.5b	37.1b
SE±		0.59	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 5: Interaction between phosphorus rate and method of lime application on number of nodules per plant of soyabean at 12WAS at Samaru, 1995.

Treatments	Lime application methods	
	Broadcasting	Banding
Phosphorus (kg P/ha)		
0	17.3d	17.0d
20	26.8c	26.9c
40	30.2b	33.1a
SE±	0.48	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 6: Interaction between lime level and method of lime application on number of nodules per plant of soyabean at 12WAS at Samaru, 1995.

Treatments	Lime application methods	
	Broadcasting	Banding
Lime (kg/ha)		
0	16.4d	19.1c
500	25.8b	26.1b
1000	32.0a	31.8a
SE±	0.48	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 7: Interaction among phosphorus rate, lime level and method of lime application on number of nodules per plant of soyabean at 12WAS at Samaru, 1995.

Lime application methods	Lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
Broadcasting	0	11.0h	18.2fg	20.0fg
	500	23.3de	20.3fg	33.9c
	1000	17.5g	41.9a	36.6bc
Banding	0	11.8h	21.1ef	24.5d
	500	20.0fg	21.1ef	37.1b
	1000	19.3fg	38.5b	37.7b
		SE±	0.84	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

4.1.7 **Nodule dry weight (g) per plant**

Maximum nodule dry weight was attained at 12WAS (Fig.7). Methods of lime application significantly influenced nodule dry weight at 6, 8 and 10WAS. At 12WAS, method of lime application had no significant effect on nodule dry weight.

Application of lime significantly influenced nodule dry weight throughout the sampling period (Fig. 7). At maximum nodule dry weight, increasing lime level from 0 to 500kg lime/ha resulted in 29.1% increase in nodule dry weight, and a further increase in lime level from 500 to 1000kg lime/ha increased nodule dry weight by 7.2%

Phosphorus application significantly increased nodule dry weight at all growth stages (Fig. 7). At 12WAS, increasing P level from 0 to 20kg P significantly increased nodule dry weight by 38.9% and a further increase of P level from 20 to 40kg P/ha resulted in 37.2% increase in nodule dry weight.

4.1.8 **Plant height.**

Maximum height was attained at 12WAS (Fig 8). Plant height was significantly affected by methods of lime application at 6, 8 and 10WAS. At 12WAS, method of lime application had no significant influence on soyabean height.

Application of lime influenced plant height at all growth stages (Fig. 8). At 12WAS, increasing lime level from 0 to 500kg lime/ha resulted in 12.2% increase in height,but a

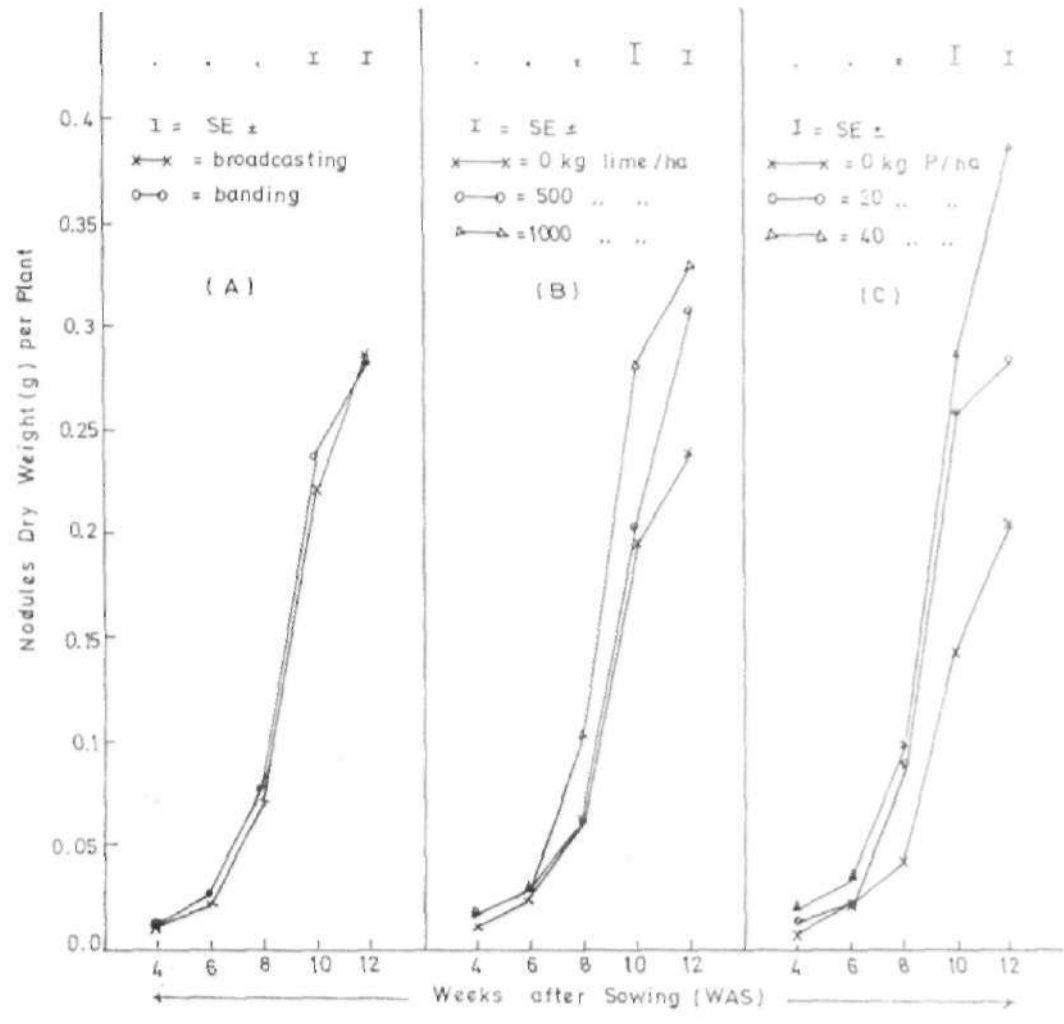


Fig. 7: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on nodule dry weight (g) per plant of soyabean at different weeks after sowing.

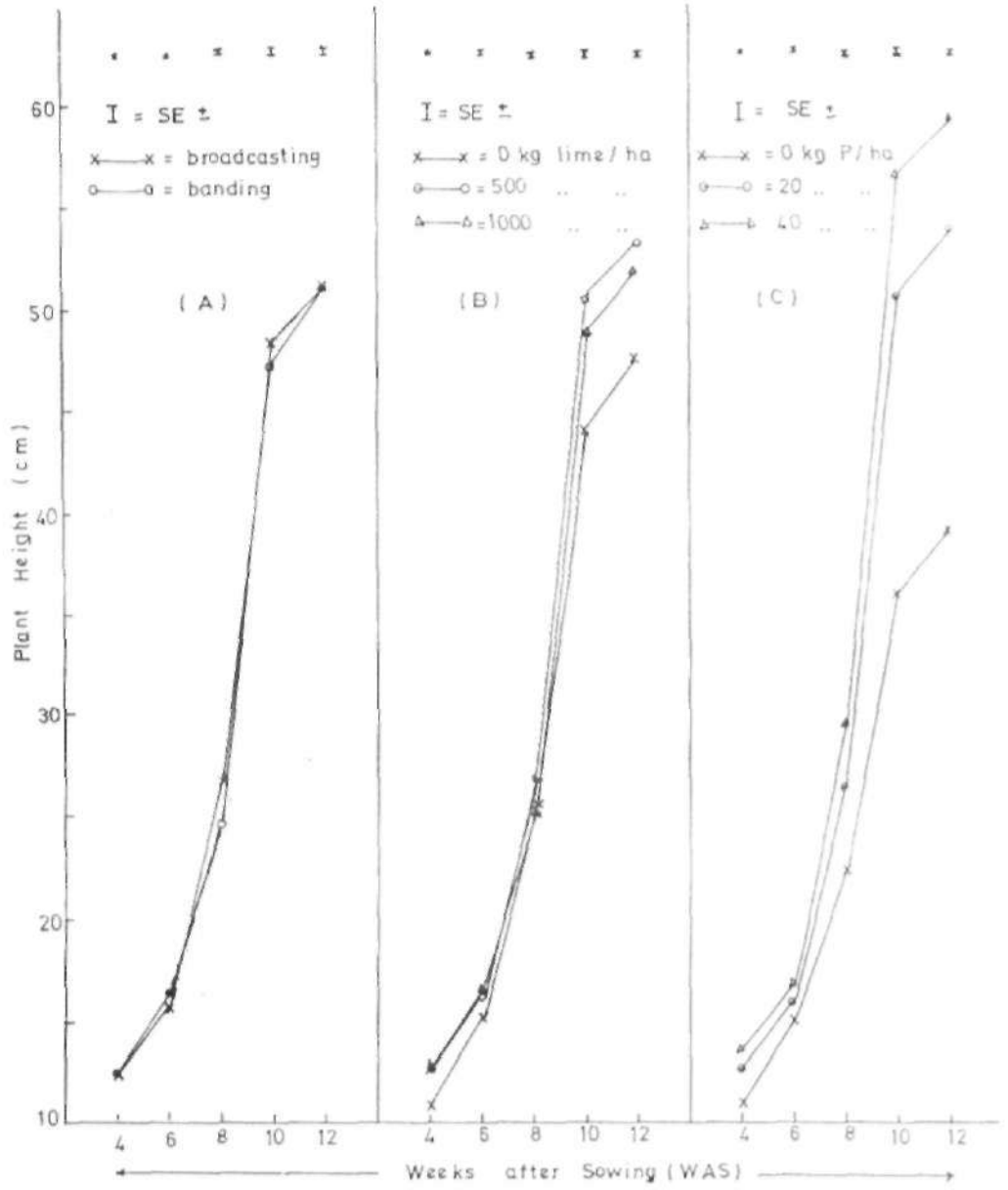


Fig. 8: Effect of method (A) and rate (B) of lime application and phosphorus level (C) on plant height (cm) of soyabean at different weeks after sowing.

further increase of lime level from 500 to 1000kg lime/ha reduced plant height by 2.8%.

Phosphorus application significantly increased plant height throughout the sampling period (Fig. 8). At 12WAS, application of 20 and 40kg P /ha increased plant height by 37.8% and 10%, respectively, compared with the zero P treatment.

Significant interactions observed were:

a) Phosphorus rate x lime level; the highest plant height was produced with application of 40kg P/ha and 500 or 1000kg lime/ha (Table 8).

b) Phosphorus rate x lime level x method of lime application; the highest height was produced with a combination of 40kg P/ha and banding of 1000kg lime/ha (Table 9).

4.1.9 Number of days to 50% flowering

Method and rate of lime application had no significant influence on number of days to 50% flowering (Table 10).

Application of 20 and 40kg P/ha significantly increased number of days to 50% flowering by 1.1% and 1.5% compared with the no P treatment, respectively.

Table 8: Interaction between rates of phosphorus and lime on plant height (cm) of soyabean at 12WAS at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	34.7e	43.7c	39.1d
20	54.2b	54.6b	53.3b
40	53.6b	61.5a	63.1a
SE±		0.55	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 9: Interaction among phosphorus rate, lime level and method of lime application on plant height (cm) of soyabean at 12WAS at Samaru, 1995.

Lime application methods	Lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
Broadcasting	0	35.0k	53.3fgh	54.7efg
	500	43.7i	51.9h	63.3ab
	1000	39.8j	55.7ef	61.3bc
Banding	0	34.5k	55.1efg	52.5fg
	500	43.7i	57.3de	59.8cd
	1000	38.4j	50.8h	64.9a
		SE±	0.78	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 10: Number of days to 50% flowering as influenced by methods and rates of lime application, and phosphorus levels at Samaru, 1995.

Treatments	Number of days to 50% flowering
Lime application method:	
Broadcasting	55.3
Banding	55.1
SE ±	0.09
Lime (kg/ha)	
0	55.0
500	55.2
1000	55.3
SE±	0.11
Phosphorus (kg P/ha)	
0	54.7b
20	55.3a
40	55.5a
SE ±	0.11

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

4.2. Effects of Methods of Lime Application, and Rates of Lime and Phosphorus on Nutrient Concentrations in Soyabean Shoot.

4.2.1 Phosphorus concentration in shoot of soyabean.

Method and rate of lime application had no significant effect on concentration of phosphorus in soyabean shoot (Table 11).

Application of 20 and 40kg P/ha significantly increased the concentration in soyabean shoot by 25.8% and 52.2%, respectively, over no P treatment.

4.2.2. Calcium concentration in shoot of soyabean.

Banding of lime significantly increased Ca concentration in soyabean shoot by 2% over broadcasting (Table 11).

On the other hand, rates of lime and phosphorus showed no significant effect on Ca concentration in soyabean shoot.

4.2.3. Nitrogen concentration in shoot of soyabean.

Broadcasting of lime gave a significant higher N concentration (17.4%) in soyabean shoot than banding of lime (Table 11).

Rates of lime and phosphorus did not significantly influence N concentration in soyabean shoot.

Table 11: Phosphorus, calcium and nitrogen concentrations (%) in shoots of soyabean as influenced by methods and rates of lime application and phosphorus levels at Samaru, 1995.

Treatments	Shoot concentration (%) of:		
	P	Ca	N
Lime application methods			
Broadcasting	0.29	0.81b	2.97a
Banding	0.30	0.98a	2.53b
SE±	0.01	0.03	0.11
Lime (kg/ha)			
0	0.30	0.88	2.79
500	0.29	0.88	2.90
1000	0.30	0.93	2.60
SE±	0.01	0.04	0.14
Phosphorus (kg P/ha)			
0	0.23c	0.85	2.65
20	0.31b	0.91	2.77
40	0.35a	0.93	2.83
SE±	0.01	0.04	0.14

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

4.3. Effect of Method and Rate of Lime Application and Phosphorus Level on Yield and Yield Components of Soyabean.

4.3.1. Grain yield (kg/ha)

Broadcasting of lime produced a significantly higher grain yield (1.6%) than banding of lime (Table 12).

Application of lime significantly influenced grain yield. Increasing lime level from 0 to 500kg lime/ha resulted in 22.7% increase in grain yield, but a further increase of lime level from 500 to 1000kg lime/ha had no significant effect on the grain yield.

Soyabean grain yield was significantly increased by 63.9% and 77.7% with the application of 20 and 40kg P/ha, respectively, over the no P treatment.

Some interactions were significant on grain yield per hectare. These interactions were:

(a) Phosphrous rate x lime level; application of 40kg P/ha and 1000 kg lime/ha produced the highest grain yield (Table 13).

(b) Phosphrous rate x lime level x method of lime application; the highest grain yield was produced with a combination of 40kg P/ha and broadcasting or banding 1000kg lime/ha (Table 14).

Table 12: Yield and yield components of soyabean as influenced by methods and rates of lime application and phosphorus levels at Samaru, 1995

	Grain yield (kg/ha)	Days to physiological maturity	100-seed weight	No. of pods/plant	Number of seeds/pod	Pod yield/plant	Total dry matter/plant	Total dry matter/ha	Shelling %	Harvest index
Lime application methods										
Broadcasting	1653a	102.6	11.26	40.4a	2.0	14.2a	171.5a	3669a	66.1	45.7
Banding	1627b	102.4	11.31	36.7b	2.1	13.1b	160.0b	3499b	65.4	46.8
SE±	8.47	0.17	0.02	0.16	0.009	0.01	1.77	48.65	0.58	0.56
Lime (kg/ha)										
0	1420b	102.4	11.26b	33.7c	2.0b	12.0c	144.9c	3211b	65.6	44.2b
500	1742a	102.4	11.20b	39.5b	2.1a	13.8b	171.0b	3707a	65.7	48.2a
1000	1758a	102.7	11.41a	42.5a	2.1a	15.1a	181.4a	3833a	65.8	46.3a
SE±	10.38	0.21	0.03	0.20	0.01	0.12	2.17	59.61	0.71	0.68
Phosphorus (kg P/ha)										
0	1114c	101.9b	11.15c	30.2c	2.0b	10.5c	122.6c	2315c	65.1b	47.9a
20	1826b	102.8a	11.30b	43.2a	2.1a	15.4a	182.0b	3930b	64.3b	46.9a
40	1980a	102.7a	11.41a	42.3b	2.1a	15.0b	192.6a	4507a	67.8a	44.0b
SE±	10.38	0.21	0.03	0.20	0.01	0.12	2.17	59.61	0.71	0.68

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 13: Interaction between rates of phosphorus and lime on grain yield (kg/ha) of soyabean at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	855h	1321f	1166g
20	1765d	1877c	1837c
40	1641e	2028b	2271a
SE±		17.97	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 14: Interaction among phosphorus rate, lime level and method of lime application on grain yield (kg/ha) of soyabean at Samaru, 1995.

Lime application methods	lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
Broadcasting	0	854i	1863d	1601e
	500	1395f	1778d	2100b
	1000	1145h	1857d	2287a
Banding	0	856i	1667e	1680e
	500	1247g	1976c	1956c
	1000	1188gh	1817d	2255a
		SE±	25.42	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

4.3.2 Number of days to physiological maturity

The number of days to physiological maturity was not significantly influenced by method and rate of lime application (Table 12).

Application of 20kg P/ha significantly increased number of days to physiological maturity by 0.9% compared with zero treatment, but no further significant increase was observed by increasing P level from 20 to 40kg P/ha.

4.3.3 100-seed weight (g)

Lime application method did not signficantly influence 100-seed weight (Table 12).

Application of 500kg lime/ha did not significantly increase 100-seed weight, but a further increased of lime level from 500 to 1000kg lime/ha significantly increased 100-seed weight by 1.9%.

Application of phosphrous at 20 and 40kg P/ha significantly increased 100-seed weight by 1.3% and 2.3%, respectively, over no P treatment.

The following interactions were significant:

(a) phosphrous rate x lime level; the highest 100-seed weight was obtained with a combination of 20kg P/ha and 0 kg lime/ha or 40kg P/ha and 1000kg lime/ha (Table 15).

(b) Phosphrous rate x method of lime application; the heaviest seeds were produced with a combination of 40kg P/ha and banding of lime (Table 16).

(c) Lime rate x method of liming; the heaviest seeds were obtained with banding of 1000kg lime/ha (Table 17).

(d) Phosphrous rate x lime level x method of liming; the highest 100-seed weight was obtained with a combination of 40kg P/ha and banding of 1000kg lime/ha (Table 18).

4.3.4 Number of pods per plant

Broadcasting of lime significantly increased number of pods per plant by 10.1% over banding (Table 12).

Number of pods per plant was significantly increased by 17.2% and 16.1% with application of 500 and 1000kg lime/ha, respectively, over the no lime treatment.

Increasing P level from 0 to 20kg P/ha significantly increase number of pods per plant by 43% but a further increase of P level from 20 to 40kg P/ha gave a significant reduction (2.1%) which was significantly higher than no P treatment by 40.1%.

Significant interactions observed were:

(a) Phosphorus rate x lime level; the highest number of pods per plant was produced with a combination of 20kg P/ha and 1000kg lime/ha (Table 19).

(b) Phosphorus rate x method of lime application; the highest pod number was obtained with a combination of 20kg P/ha and broadcasting of lime (Table 20).

Table 15: Interaction between rates of phosphorus and lime on 100-seed weight (g) of soyabean at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	10.88e	11.16d	11.43b
20	11.65a	11.11d	11.13d
40	11.24cd	11.34bc	11.66a
SE±		0.04	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 16: Interaction between phosphorus rate and method of lime application on 100-seed weight (g) of soyabean at Samaru, 1995.

Treatments	Lime application methods:	
	Broadcasting	Banding
Phosphorus (kg P/ha)		
0	11.26bc	11.04d
20	11.22c	11.37b
40	11.31bc	11.52a
SE±	0.04	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 17: Interaction between lime level and method of lime application on 100-seed weight (g) of soyabean at Samaru, 1995.

Treatments	Lime application methods:	
	Broadcasting	Banding
Lime (kg/ha)		
0	11.24c	11.27bc
500	11.30b	11.10d
1000	11.25c	11.56a
SE±	0.04	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 18: Interaction among phosphorus rate, lime level and method of lime application on 100-seed weight (g) of soyabean at Samaru, 1995.

Lime application methods	lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
Broadcasting	0	10.95hi	11.92ab	10.85hi
	500	11.03gh	11.06gh	11.83bc
	1000	11.81bc	10.69j	11.24fg
Banding	0	10.80ij	11.37ef	11.64cd
	500	11.29f	11.17fg	10.85hi
	1000	11.04gh	11.57de	12.08a
	SE±	0.06		

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 19: Interaction between rates of phosphorus and lime on number of pods per plant of soyabean at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	20.6g	34.6f	35.4f
20	42.0c	40.0d	47.6a
40	38.5e	43.9b	44.4b
SE±		0.35	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 20: Interaction between phosphorus rate and method of lime application on number of pods per plant of soyabean at Samaru, 1995.

Treatments	Lime application methods:	
	Broadcasting	Banding
Phosphorus (kg P/ha)		
0	30.5d	29.9d
20	46.8a	39.6c
40	44.0b	40.5c
SE±	0.28	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

(c) Phosphorus rate x lime level x method of lime application; the highest number of pods per plant was produced with a combination of 20kg P/ha and broadcasting of 1000kg lime/ha (Table 21).

4.3.5 Number of seeds per pod

There was no significat differences between the two methods of lime application on number of seeds per pod (Table 12).

Increasing lime level from 0 to 500kg lime/ha significantly increased number of seeds per pod by 5.0%, but a further increase of lime level from 500 to 1000kg lime/ha gave no significant increase.

Application of 20kg P/ha significantly increased number of seeds per pod by 5.0% over no P treatment, but a further increased of P level from 20 to 40kg P/ha produced no significant increase.

4.3.6. Pod yield per plant

Broadcasting of lime produced a significant 8.4% increase in pod yield per plant compared with banding (Table 12).

Application of 500 and 1000kg lime/ha significantly increased pod yield per plant by 15% and 25.8%, respectively, over no lime treatment.

Table 21: Interaction among phosphorus rate, lime level and method of lime application on number of pods per plant of soyabean at Samaru, 1995.

Lime application methods	lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
	0	21.2h	44.3c	41.2d
Broadcasting	500	38.5e	38.6e	47.1b
	1000	31.7g	57.3a	43.9c
	0	20.0h	39.6e	35.8f
Banding	500	30.7g	41.3d	40.7d
	1000	39.1e	37.9e	44.9c
		SE±	0.49	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Increasing P level from 0 to 20kg P/ha significantly increased pod yield by 46.7%, but a further increase of P level from 20 to 40kg P/ha significantly reduced pod yield by 2.6% which was significantly higher than 0kg P/ha by 42.9%.

4.3.7 Total dry matter plant

Total dry matter per plant was significantly increased by method of lime application (Table 12). The broadcast method gave a significantly higher total dry matter per plant (7.2%) than band method.

Application of 500 and 1000kg lime/ha significantly increased total dry matter per plant by 18% and 25.2% over no lime treatment, respectively.

Total dry matter per plant was significantly increased by 48.5% and 57.1% with the application of 20 and 40kg P/ha, respectively, over no P treatment.

4.3.8 Total dry matter per hectare

Broadcasting of lime significantly increased total dry matter per hectare by 4.9% over banding (Table 12).

Application of 500kg lime/ha significantly increased total dry matter per hectare by 15.4% over no lime treatment but application of 1000kg lime/ha did not differ significantly from applying 500kg lime/ha.

Total dry matter per hectare was significantly

increased by 69.8% and 94.7% with the application of 20 and 40kg P/ha, respectively, over the no P treatment.

The following interactions were significant:

(a) Phosphrous rate x lime level; the highest total dry matter per hectare was produced with application of 40kg P/ha and 500 or 1000kg lime/ha (Tabe 22).

(b) Lime level x method of lime application; the highest total dry matter per hectare was obtained by broadcasting 500kg lime/ha or banding 1000kg lime/ha (Table 23).

(c) Phosphrous rate x lime level x method of lime application; the highest total dry matter per hectare was obtained with applications of 40kg P/ha and broadcasting of 500kg lime/ha or banding of 1000kg lime/ha (Tabe 24).

4.3.9 Shelling percentage

Methods of lime application and lime rates had no significant effect on shelling percentage (Table 12).

Increasing P level from 0 to 20kg P/ha had no significant effect on shelling percentage but a further increase of P level from 20 to 40kg P/ha significantly increased shelling percentage by 5.4%.

Table 22: Interaction between rates of phosphorus and lime on total dry matter per hectare of soyabean at Samaru, 1995.

Treatments	Lime (kg/ha)		
	0	500	1000
Phosphorus (kg P/ha)			
0	2011e	2544d	2389d
20	3689c	3844c	4256b
40	3933b	4733a	4856a
SE±		103.24	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 23: Interaction between lime level and method of lime application on total dry matter per hectare of soyabean at Samaru, 1995.

Treatments	Lime application methods:	
	Broadcasting	Banding
Lime (kg/ha)		
0	3370c	3052d
500	3889a	3526bc
1000	3748ab	3919a
SE±	84.29	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 24: Interaction among phosphorus rate, lime level and method of lime application on total dry matter per hectare of soyabean at Samaru, 1995.

Lime application methods	Lime (kg/ha)	Phosphorus (kg P/ha)		
		0	20	40
Broadcasting	0	2022g	3978cd	4111cd
	500	2533f	3911cd	5222a
	1000	2400fg	4111cd	4734ab
Banding	0	2000g	3400e	3756de
	500	2555f	3778de	4245bcd
	1000	2378fg	4400bc	4978a
		SE±	146.02	

Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

4.3.10. Harvest index.

Harvest index was not significantly affected by method of lime application (Table 12).

Application of 500kg lime/ha gave a significant 9.0% increase in harvest index over no lime treatment but a further increase of lime level from 500 to 1000kg lime/ha had no significant effect.

Increasing P level from 0 to 20kg P/ha gave no significant effect on harvest index, however, increasing P level from 20 to 40kg P/ha significantly reduced harvest index by 6.2%.

4.4 Correlation Analysis

The results of the partial correlation analysis between yield, growth and yield components of soyabean are shown in Table 25. Grain yield was found to highly significantly and positively correlate with the leaf area index, number of leaves per plant, number of primary branches per plant, number of nodules per plant, plant height, number of days to 50% flowering, number of pods per plant, pod yield per plant, number of seeds per pod, 100-seed weight and total dry matter per hectare. However, shelling percentage was not significantly but positively correlated with grain yield, and harvest index was not significantly but negatively correlated with grain yield per hectare.

Table 25: Matrix of coefficient of correlation between yield, growth and yield components of soyabean at Samaru, 1995

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	0.70**	1.00												
3	0.72**	0.63**	1.00											
4	0.87**	0.80**	0.72**	1.00										
5	0.94**	0.73**	0.73**	0.90**	1.00									
6	0.63**	0.43**	0.57**	0.60**	0.57**	1.00								
7	0.64**	0.72**	0.73**	0.77**	0.64**	0.58**	1.00							
8	0.62**	0.64**	0.77**	0.73**	0.62**	0.58**	0.89**	1.00						
9	0.27*	0.25	0.20	0.32*	0.26	0.09	0.15	-0.07	1.00					
10	0.39**	0.25	0.15	0.32*	0.28*	0.06	0.14	0.19	0.26	1.00				
11	0.20	0.07	-0.01	0.19	0.26	-0.03	0.10	-0.15	0.24	-0.00	1.00			
12	0.82**	0.72**	0.76**	0.93**	0.83**	0.57**	0.74**	0.70**	0.31*	0.35**	0.16	1.00		
13	-0.12	0.05	-0.12	-0.09	-0.09	-0.12	0.05	-0.03	0.23	-0.05	-0.03	-0.36**	1.00	
14	0.83**	0.78**	0.77**	0.96**	0.86**	0.56**	0.79**	0.73**	0.46**	0.35**	0.17	0.94**	-0.02	1.00

* = significant at 5% level of significance.
** = significant at 1% level of significance.

1 = Number of leaves per plant at 12WAS;
2 = Number of primary branches per plant at 12WAS;
3 = Number of nodules per plant at 12WAS;
4 = Plant height (cm) at 12 WAS;
5 = Leaf area index at 10WAS;
6 = Days to 50% flowering;
7 = Number of pods per plant at harvest;
8 = Pod yield per plant at harvest;
9 = Number of seeds per pod at harvest;
10 = 100-seed weight (g) per plant at harvest;
11 = Shelling percentage;
12 = Total dry matter per hectare;
13 = Harvest index;
14 = Grain yield (kg/ha).

4.5 Regression Studies

The regression of lime levels against yield was found to be quadratic and fitted the equation:

$Y = 1420 + 949.7x - 611.7x^2$.....(Fig. 9)

From this equation the optimum rate of lime for soyabean was calculated to be 780kg lime/ha. Similarly, regression of phosphorus levels against grain yield was found to be quadratic and fitted the equation:

$Y = 1114.1 + 49.5x - 0.7x^2$ .....(Fig. 10)

From this equation the optimum rate of phosphorus for soyabean was calculated to be 35.4kg P/ha.

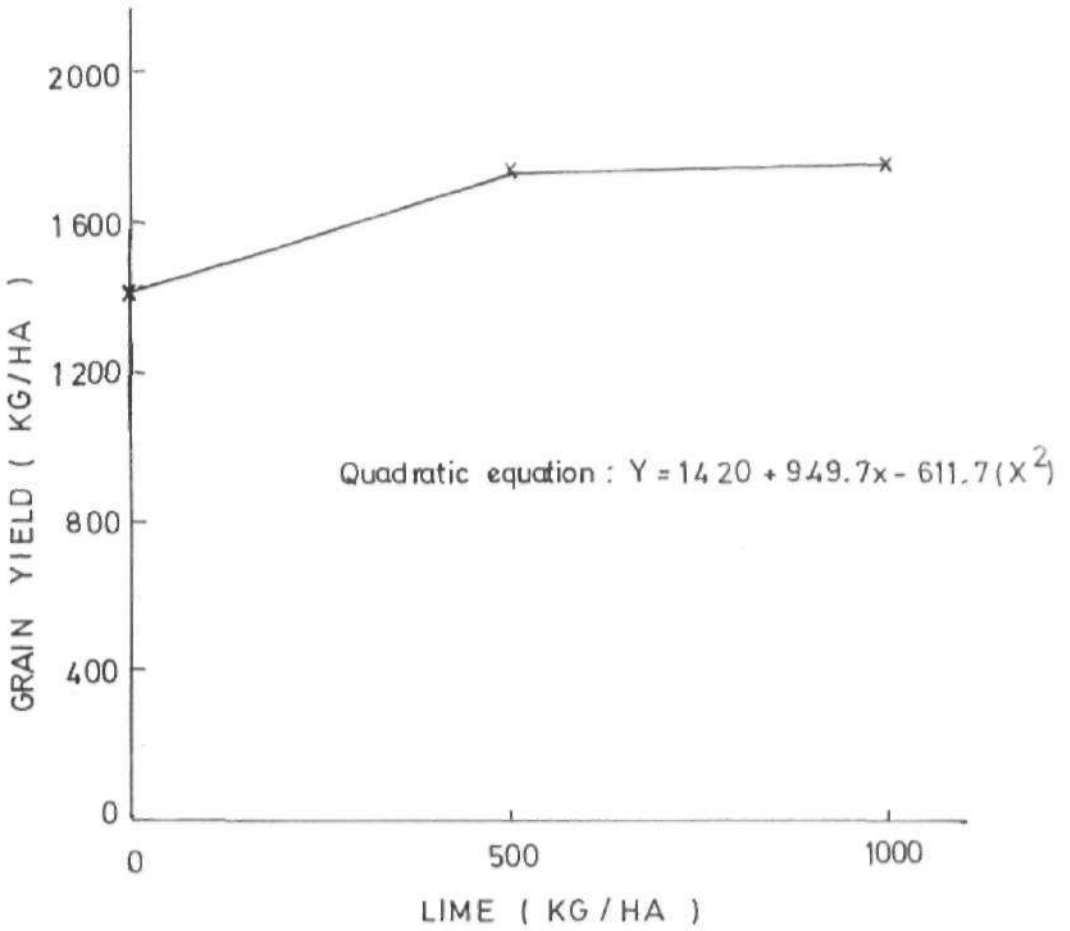


Fig.9 : Regression of grain yield of soyabean against Lime level

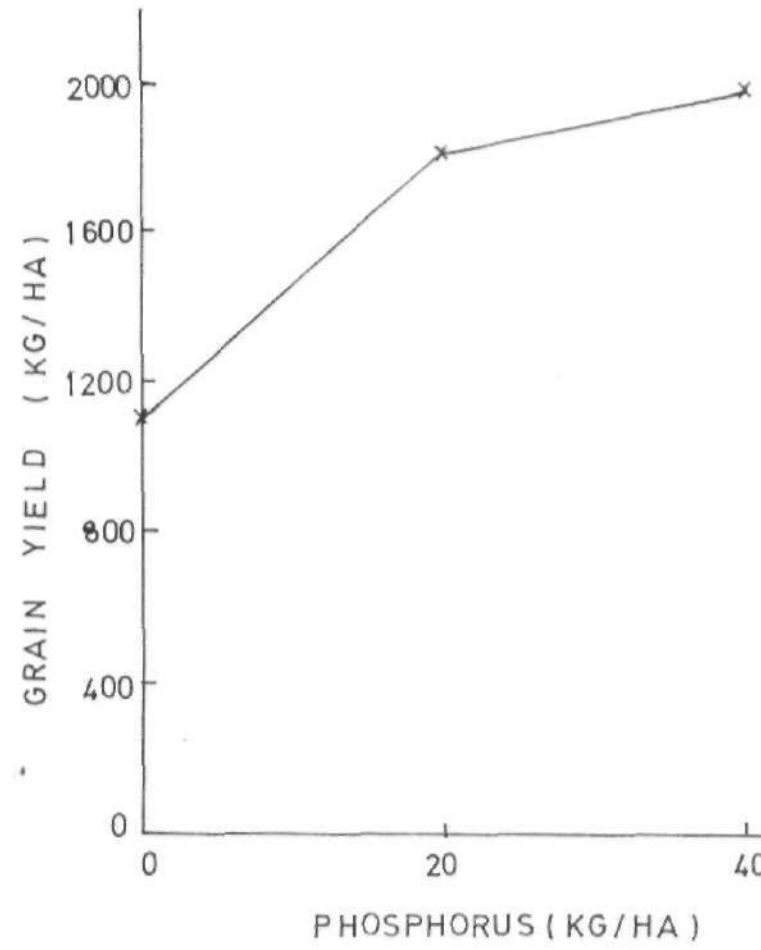


Fig.10 : Regression of grain yield of Soyabean against phosphorus level.

Quadratic equation : $Y = 1114.1 + 49.5X - 0.7(X^2)$

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Methods of Lime Application on Soyabean

Banding of lime performed significantly better than broadcasting of lime on leaf area index, number of primary branches and number of nodules. This performance could be attributed to the fact that localized placement of lime achieved by banding provided for an early growth stimulation because of localized neutralization of soil acidity which caused rapid growth and development of roots that were in immediate locality of the band lime, thus improving nutrients absorption. However, the two methods of liming did not differ significantly on number of leaves, leaf dry weight, stem dry weight, nodule dry weight, plant height and number of days to 50% flowering. This may be that none of the two methods of liming could hasten the reaction time of lime with soil which is normally slow, hence lack of effect of liming methods on most of the growth parameters.

Broadcasting of lime was significantly superior to banding of lime on yield and yield components of soyabean. This is because broadcasting of lime caused the production of higher pod yield per plant, number of pods per plant, total dry matter per plant, total dry matter per hectare, grain yield per hectare than banding of lime. This response could be due to the reason that uniform placement of lime achieved by broadcasting facilitated a gradual and

widespread neutralization of soil acidity or speedy elimination of Al and Mn toxicity throughout the root zone, allowing more roots to come in contact with neutralized soil, consequently enhancing absorption of nutrients especially phosphorus. However, the two methods of liming were similar on number of days to physiological maturity, 100 - seed weight, number of seeds per pod, shelling percentage and harvest index. This may be that both methods of liming were not important on the parameters because of the same quantity of lime applied, hence causing the methods to have equal effect on the parameters.

Generally, a significant higher grain yield per hectare was obtained in broadcast method of liming than band method. This increase in yield could be attributed to the fact that broadcasting of lime ensured better root growth and development which consequently improved nutrients interception, hence increased grain yield. Another reason for the increased yield may be due to significant influence of broadcast method of liming on yield parameters. This result agrees with the findings of Carvalho and Meurer (1980) who reported that broadcast method of liming produced a significant higher yield of soyabean than band method.

5.2 **Effect of Lime Levels on Vegetative Growth of Soyabean**

Liming of soil resulted in increases in the leaf area index, number of leaves, stem dry weight, number of primary

branches, number of nodules, nodule dry weight and plant height. These increases in growth characters could perhaps be attributed to the ability of lime to promote root growth and development, and consequently enhanced availability and absorption of phosphorus and other nutrients for a more vigorous growth. Another reason for these increases may be that application of lime reduced exchangeable and water soluble Al, increased water soluble Ca and gave a favourable soil pH for rhizobium activity (Mengel and Kamprath, 1978). The overall effect of these increases was the more robust growth of soyabean plants grown on limed soil than those on the control. This result agrees with earlier reports that lime application gave significant growth responses of soyabean (Mengel and Kamprath, 1978; Nobel et al., 1984).

On the other hand, application of lime did not show a significant effect on number of days to 50% flowering. This may be that the lime does not hasten or delay flowering growth of soyabean. Similarly, lime application had no significant effect on leaf dry weight. This could be due to the fact that photosynthates produced during the later growth stages were partitioned to pod development compared with early growth stages when the photosynthates produced were directed towards vegetative growth.

5.3 Effect of Lime Levels on Yield and Yield Components of Soyabean

Application of lime caused the production of higher pod

yield per plant, more pods per plant, more seeds per pod, heavier seeds, and more total dry matter per plant and per hectare than the control. These increases in yield components may be attributed to increases observed on growth parameters which resulted in good crop growth to achieve high yield. Another possible reason for the increased yield components may be due to the ability of the lime to supply Ca and to precipitate the exchangeable Al which the amount present in soil often being inversely related to yield (Cooke, 1982). However, number of days to physiological maturity was not significantly affected by lime application. This could be that lime does not hasten or delay maturity of soyabean. Similarly, shelling percentage was not significantly influenced by liming. This could be that lime application increased both weight of shelled grains and weight of unshelled pods of soyabean by the same magnitude.

The application of 500kg lime/ha significantly increased grain yield per hectare but a further increase of lime level to 1000kg lime/ha produced no significant increase in grain yield. This increase in yield could be due to the ability of lime to improve nutrients availability and stimulate the development of fine root system (Martini and Multer, 1989) and consequently enhanced interception and absorption of nutrients especially phosphorus. The increase in yield could also be attributed to significant increases observed on the yield components as a result of liming.

The significant increase in grain yield of soyabean as a result of soil liming has been reported by many workers (Samonte, 1985; Samarao et al., 1986 and Prasad, 1992). The regression of grain yield of soyabean on lime gave the calculated optimum rate of 780kg lime/ha. This rate gave the calculated grain yield of 1789kg/ha which was slightly higher than grain yield (1758kg/ha) obtained in the field with application of 1000kg lime/ha. This indicated that beyond 780kg lime/ha the grain yield had started declining.

5.4 Effect of Phosphorus Rates on Vegetative Growth of Soyabean

Application of phosphorus enhanced vegetative growth of soyabean. This is because phosphorus application caused increases in the leaf area index, number of leaves, leaf dry weight, stem dry weight, number of primary branches, number of nodules, nodule dry weight, plant height and number of days to 50% flowering. These increases in growth parameters confirmed the importance of phosphorus as an essential nutrient required for rapid vegetative growth of soyabean because of its role in the formation of high energy molecules, synthesis of cell constituents, and in the formation and translocation of carbohydrates, fatty acids and nucleo proteins (DeMooy et al., 1973). The overall effect of these increases in growth characters was the production of bigger and more robust plants grown on soil

that received phosphorus than those on the control. This result is in agreement with findings of Nangju (1975) who reported that soyabean needs 20 - 40kg P/ha for optimum growth.

On the other hand, plants grown on plots without applied phosphorus were short and stunted. Their leaves were few and pale in colour. They were low in leaf area index. Based on this poor canopy development, these plants were not able to give a complete canopy cover of the ground which indicated that sunlight was not sufficiently utilized. This is in agreement with finding of Chiezey (1990) who reported poor canopy development of soyabean plants which received no phosphorus fertilizer.

5.5 Effect of Phosphorus Rates on Yield and Yield Components of Soyabean

Application of phosphorus fertilizer resulted in increases in the number of days to physiological maturity, pod yield per plant, number of pods per plant, number of seeds per pod, 100-seed weight, total dry matter per plant, total dry matter per hectare and shelling percentage. These increases could be attributed to low level of available P in the experimental soil (Appendix 1). The increases in yield components could also be as a consequence of the increases observed on nodule number and dry weight which enhanced N - fixation to achieve high yield. Chiezey (1990) reported

similar increases in number of pod per plant, pod yield per plant, 100-seed weight and total dry matter after phosphorus application.

The application of phosphorus up to 40kg P/ha significantly increased grain yield per hectare. This increase in grain yield could be due to the fact that the plants that did receive phosphorus had higher leaf area index and had more leaves than those plants which received no phosphorus, hence greater photosynthetic capacity and rapid assimilates translocation for pod formation and grain filling. Another reason for the increase in yield could be the positive effects of phosphorus on yield components. The significant increase in grain yield is in conformity with those reported by many researchers (Olufajo, 1990; Naidu and Pillai, 1991 and Chiezey et al., 1992). The regression of grain yield on phosphorus gave a curvilinear response with a calculate optimum rate of 35.4kg P/ha. This rate gave a calculated optimum grain yield of 1989kg/ha which was slightly higher than grain yield (1980kg/ha) obtained in the field with application of 40kg P/ha. This indicated that beyond 35.4kg P/ha the grain yield had started declining. This figure (35.4kg P/ha) falls within the range given by Pal et al. (1989) who reported that soyabean in Nigerian savanna required 24-39kg P/ha for maximum yield. On the other hand, unfertilized plants because of relatively low level of P in the experimental soil (Appendix 1) were

competing for small amount of the nutrient in the soil which was not sufficient to sustain higher grain yield.

Harvest index was not significantly influenced by application of 20kg P/ha which means phosphorus application increased both grain yield and total dry matter by the same magnitude. However, a further increase of P rate from 20 to 40kg P/ha significantly reduced harvest index which indicates that the rate of increase caused by P application is more in vegetative organs than grain yield.

5.6 Effect of Methods of Lime Application and Rates of Lime and Phosphorus on Nutrient Concentrations in Soyabean Shoot.

5.6.1 Effect of methods of lime application on nutrient concentrations

Methods of lime application had no discernible effect on P concentration in soyabean shoot. This could be attributed to the fact that both methods of liming increased P availability by the same magnitude. However, banding of lime gave a significant higher Ca concentration in soyabean shoot than broadcasting of lime. This may be that banding of lime stimulated early root growth which enhanced calcium absorption. Similarly, broadcasting of lime produced higher N concentration in soyabean shoot than banding of lime. This could be that broadcasting of lime ensured prolific root growth, thus ensuring higher N uptake.

5.6.2 Effect of lime levels on nutrient concentrations

Lime application had no significant influence on P concentration. This may be attributed to availability of Ca contained in the applied fertilizer (SSP) to the soyabean plants thus addition of more lime may not confer any beneficial effect on P uptake. Another reason could be that most of the P must have been mobilized to nodules because nodules form a strong sink for P (Graham and Rosas, 1979). This result conforms with earlier report that lime had no significant effect on P uptake of soyabean (Scherer et al., 1979). Similarly, application of lime had no significant effect on Ca concentration of soyabean shoot. This could be attributed to the dillution effect of lime because most of the Ca from the lime must have been used up for nodule initiation. According to Lowther and Loneragan (1968), legumes require higher Ca for initiation of nodulation as compared to that needed for growth. This result agrees with the finding of Rosolem and Nakagawa (1990) that lime had no significant effect on Ca concentration of soyabean leaves. Lime application did not also significantly increase N concentration in soyabean shoot. This could probably be due to dilution effect of lime brought about by the favourable growth response. This result agrees with earlier report that lime had no significant effect on total plant N content of soyabean (Samarao et al., 1986).

5.6.3. Effect of phosphorus rates on nutrient concentrations

P concentration in soyabean shoot significantly increased with P application. The response of P concentration to applied P should probably be expected because soil-applied phosphorus was available to plants, hence the observed increase in P concentration. This result agrees with that of Kovacevic (1993) who reported that P application increased leaf P concentration. However, Ca and N concentrations in soyabean shoot were not significantly affected by phosphorus application. Lack of response of Ca and N concentrations to applied P could probably be due to the dilution effect of phosphorus fertilizer caused by the observed increases in growth parameters especially leaf and stem dry weight.

5.7 Interactions

5.7.1 Phosphorus rate x lime level

The highest values obtained on number of nodules (40.2), plant height (61.5 and 63.1cm), number of pods (47.6), total dry matter (4733 and 4856kg/ha), and grain yield (2271kg/ha) as a result of a significant interaction between phosphorus rate and lime level could be attributed to the effect of lime on improving root exploitation of available P in the soil (Friesen et al., 1980). The heaviest seeds (11.65 and 11.66g), that were produced in

this significant interaction, indicates that initial soil pH caused the exploitation of fertilizer P up to 20kg P/ha or that pH achieved by liming at highest level improved root growth which consequently enhanced exploitation of applied P.

5.7.2 Phosphorus rate x method of lime application

The highest leaf area index (6.37) and number of nodules (33.1), and heaviest seeds (11.52g), that were produced in significant phosphorus rate x method of liming, could probably be attributed to the effect of lime banding in increasing root growth which consequently enhanced fertilizer P utilization up to 40kg P/ha. The highest number of pods (46.8) produced in this significant interaction could be attributed to the fact that broadcasting of lime allowed more roots to come in contact with neutralized soil and consequently, enhanced absorption of applied P up to 20kg P/ha.

5.7.3. Lime level x method of lime application

The highest leaf area index (5.55 and 5.70) and heaviest seeds (11.56g), that were obtained in a significant lime level x method of lime application, could be attributed to the fact that lime banding caused rapid growth and development of roots that were in immediate locality of the band lime, thus improving nutrients absorption. The highest

number of nodules (32.0 and 31.8) obtained in this significant interaction could be attributed to the effect of both methods of liming in achieving similar pH which was suitable for maximum response of the nodules. The highest total dry matter (3889 and 3919kg/ha) obtained in this significant interaction may be due to the reason that broadcasting of 500kg lime/ha and banding of 1000kg lime/ha achieved similar pH which enhanced growth.

5.7.4. **Phosphorus rate x lime level x method of lime application**

The highest leaf area index (6.99), tallest plants (64.9cm), heaviest seeds (12.08g) and highest grain yield (2255 and 2287kg/ha) obtained in significant phosphorus rate x lime level x method of lime application could be attributed to the effect of lime to improve the exploitation of soil and fertilizer P as a result of improved root growth (Friesen et al., 1980). The highest number of nodules (41.9) and pods (57.3), that was obtained in this significant interaction, indicates that application of 40kg P/ha might be inhibiting increased performance of the parameters in the presence of the highest level of broadcast lime. The highest total dry matter (5222 and 4978kg/ha) obtained in this significant interaction could be attributed to reason that broadcasting of 500kg lime/ha and banding of 1000kg lime/ha achieved similar pH which was suitable for the exploitation of applied P for maximum response of the parameter.

5.8 Correlation

Highly significant and positive correlations were observed between the grain yield per hectare and leaf area index, number of leaves per plant, number of primary branches per plant and plant height. This may probably be due to the fact that all these parameters are important determinants of photosynthetic activity and translocation of assimilates, and hence high grain yield. Similarly, the number of nodules had a significant and positive correlation with grain yield. This is because the number of nodules is an important determinant of amount of N fixed by soyabean plant. The significant and positive correlation between grain yield and number of days to 50% flowering may be attributed to the fact that this character directly determines the amount of photosynthates available for grain accumulation.

Significant and positive correlations were observed between grain yield per hectare and pod yield per plant, number of pods per plant, number of seeds per pod, 100-seed weight and total dry matter per hectare. This could be due to the fact that these parameters are the major yield components. Thus, they determine grain yield of soyabean. These findings conform with the result of Chiezey (1990) who identified number of pods per plant and 100-seed weight as the two important yield contributing characters.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

A field experiment on effect of methods and rates of lime application and different phosphorus levels on growth and yield of soyabean (Glycine max (L.) Merrill) was carried out during the 1995 cropping season at the Agricultural Research Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria. The treatment tested consisted of two methods of lime application (broadcasting and banding) and three levels each of lime (0, 500 and 1000kg lime/ha) and phosphorus (0, 20 and 40kg P/ha). Treatments were arranged in all possible combinations and laid out as a randomized complete block design.

Band method of lime application performed better than broadcast method on leaf area index, number of primary branches, number of nodules, and Ca concentration in soyabean shoot but broadcast method produced significant higher increases than band method on N concentration in soyabean shoot, number of pods per plant, pod yield per plant, total dry matter per plant, total dry matter per hectare and grain yield per hectare. However, the two methods of liming showed similarities on number of leaves, leaf dry weight, stem dry weight, nodule dry weight, plant height, number of days to 50% flowering, number of days to physiological maturity, 100-seed weight, number of seeds per

pod, shelling percentage, harvest index and P concentration in soyabean shoot.

Lime application was accompanied by significant increases in grain yield per hectare, growth and yield components of soyabean. However, lime application showed no significant effect on leaf dry weight, number of days to 50% flowering, number of days to physiological maturity, shelling percentage, and P, Ca and N concentrations in soyabean shoot. The grain yield per hectare was significantly increased with application of 500kg lime/ha but a further increase at 1000kg lime/ha was not significant. Regression analysis studies showed a response of grain yield to lime which resulted in an optimum rate of 780kg lime/ha.

Application of phosphorus resulted in significant increases in grain yield per hectare, growth and yield components. However, P application gave a significant reduction in harvest index. The grain yield per hectare was significantly increased with increasing P levels up to 40kg P/ha. Regression analysis showed a curvilinear response of grain yield to phosphorus which resulted in optimum rate of 35.4kg P/ha. Application of phosphorus increased P concentration in soyabean shoot, however, phosphorus application had no significant effect on Ca and N concentrations in soyabean shoot.

A significant interaction between phosphorus rate and

lime level on grain yield per hectare indicated that the combined application of 40kg P/ha and 1000kg lime/ha gave the highest grain yield. Similarly, a significant interaction among phosphorus rate, lime level and method of lime application on grain yield per hectare also showed that the combined application of 40kg P/ha and broadcasting or banding of 1000kg lime/ha gave the highest grain yield.

Grain yield had highly significant and positive correlations with leaf area index, number of leaves per plant, number of primary branches per plant, number of nodules per plant, plant height, number of days to 50% flowering, number of pods per plant, pod yield per plant, number of seeds per pod, 100-seed weight and total dry matter per hectare.

Based on the results obtained from this study, it can be suggested that broadcast method of lime application was better than band method because of its significant influence on grain yield and yield components. The optimum rates of phosphorus and lime were 35.4 kg P/ha and 780kg lime/ha, respectively, for maximum growth and yield of soyabean at Samaru under similar soil and weather conditions used in this experiment.

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APPENDIX

Appendix 1: Physical and chemical properties of the soil from the experimental site at Samaru before sowing, and compositions of lime used for the experiment.

Soil Characteristics	Soil depth (0-30cm)
Particle size (%)	
Clay	24
Silt	44
Sand	32
Textural class	Loam
Chemical properties	
pH in water (1:2.5)	5.5
pH in 0.01M $Cacl_2$(1:2.5)	4.9
Organic carbon (%)	0.44
Available P(ppm)	4.48
Total N (%)	0.04
Exchangeable bases (Meq/100g of soil)	
Ca	4.0
Mg	1.17
K	0.21
Na	0.26
C.E.C	8.30
Lime compositions	
Ca(%)	18.75
Mg(%)	0.20
K(%)	0.05
Na(%)	0.23
P(%)	0.01
Co_3	47

Appendix 2: Mean total rainfall, temperature and relative humidity of ten days interval during the period of the experiment at Samaru in 1995.

Months	Days	Total rainfall (Mm)	Temperature		Relative Humidity	
			Max	Min	AM	PM
June	11-20	66.4	32.4	13.9	76.1	45.1
	21-30	19.6	29.5	18.8	78.6	58.6
July	1-10	36.8	28.9	21.8	79.6	59.6
	11-20	52.3	30.2	22.7	79.4	60.0
	21-31	42.6	36.4	20.7	83.5	81.8
August	1-10	88.4	28.7	17.8	84.5	73.9
	11-20	73.6	29.1	19.5	82.8	73.1
	21-31	96.7	31.3	22.9	86.4	80.3
September	1-10	39.3	29.5	21.9	81.9	78.3
	11-20	80.5	29.4	18.9	81.6	68.7
	21-30	39.3	30.9	20.5	80.5	62.7
October	1-10	32.5	31.1	20.1	77.8	74.1
	11-20	-	32.6	18.7	71.2	44.6
	21-31	-	35.4	20.1	80.6	58.0

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