EFFECT OF SPATIAL ARRANGEMENT AND NITROGEN LEVELS ON YIELD OF POTATOES AND BEANS GROWN AS INTERCROPS

BY

ROSE A. NYANGA

A thesis submitted in partial fulfillment for the degree of Master of Science (AGRONOMY),

Department of Crop Science,

Faculty of Agriculture

In The

UNIVERSITY OF NAIROBI

1998

DECLARATION:

This thesis is my original work and has not been presented for a degree in any other university.

Awuor .... 24th August 1998

Nyanga Rose Awuor **Date**

This thesis has been submitted for examination with my approval as the university supervisor

Nyabundi .... 24th August 1998.

Dr. J.O. Nyabundi **Date**

DEDICATION:

To my beloved husband Hesbon who gave me all the support and encouragement during the time of doing this work.

ACKNOWLEDGEMENTS:

My special thanks goes to my supervisor Dr. J.O. Nyabundi of the Department of Crop Science, University of Nairobi for the constructive criticisms, helpful suggestions and the encouragement he offered to me during this study.

My sincere appreciation goes to the German Academic Exchange Service (DAAD) through the University of Nairobi for the award of a two year scholarship which enabled me to carry out this study.

I am greatly indebted to my family for their patience, encouragement and moral support which contributed significantly to the completion of this work. Lastly I wish to thank Helen N. Muthui for typing the whole thesis from it's first draft.

TABLES OF CONTENTS

LIST OF APPENDICES

SEASON ONE

SEASON TWO

LIST OF TABLES

Table: **SEASON ONE**

SEASON TWO

ABSTRACT

Two field experiments were conducted at the University of Nairobi's Faculty of Agriculture farm (Field Station) to investigate the effect of planting patterns (PP) and nitrogen (N) application on growth and yield of intercropped potatoes and beans. Two varieties (V) of potatoes, the early maturing variety Annette (V_1) and the late maturing variety B53 (V2) were intercropped with the early maturing Rosecocco (GLP-2) variety of beans during the short rains of November - March 1993 and long rains of May - August, 1994. The treatments used were four planting patterns, four nitrogen levels and two potato varieties, tested in a factorial experiment laid out in a completely randomised block design with three replicates. The planting patterns consisted of sole crop of potatoes or beans (PP1), potatoes and beans in alternate rows (PP2), potatoes and beans in alternate hills within the row (PP3) and potatoes and beans in the same hill (PP4). The nitrogen levels were 0kg/ha (N1), 37.5kg/ha (N2), 75kg/ha (N3) and 112.5kg/ha (N4). During growth, plants were sampled for dry matter, nodule number and nodule weight determination every fortnight starting from four weeks after emergence. At maturity, yield and yield components were determined for both beans and potatoes.

Results showed that potato dry matter yield in sole crop out yielded the other planting patterns early in the season upto 6 weeks after emergence and beyond this, those planted on the same hill with beans were significantly higher than alternate hill and alternate row patterns. The higher nitrogen levels of 75kg/ha and 112.5kg/ha gave sole crop dry matter yields that were significantly higher than the intercrop patterns. Bean dry matter yields of sole crop and alternate rows were statistically similar at the lower nitrogen levels of 0 and 37.5kg/ha nitrogen but as the nitrogen was increased to 75kg/ha and 112.5kg/ha the sole crop out yielded all the intercropped intercropped planting patterns.

At zero nitrogen level, intercropping in the same hill increased potato tuber yields by 3.8% and 15.2% in Annette and B53, respectively, compared to intercropping in alternate rows, in the first season. In the second season same hill yields were higher than alternate row yields by 10.1% and 12.3% for Annette and B53 respectively. Potato yield advantage arising from increased proximity between the intercrop species disappeared at higher nitrogen levels of 75kg/ha and 112.5 kg/ha. Sole beans yielded significantly more than beans in the intercropped treatments. Bean yield responded positively to nitrogen fertilizer but higher nitrogen levels depressed this parameter in some cases. Intercropping had yield advantages over monocropping. Land equivalent ratios increased with increasing intimacy between the intercrops especially under low nitrogen. The land equivalent ratio values for same hill planting were significantly higher than for the other intercrop patterns of alternate row and alternate hills at the low nitrogen levels of 0 and 37.5Kg/ha. The land equivalent ratio parameter declined with increase in nitrogen fertilizer to 75 and 112.5kg/ha., with the same hill intercropping exhibiting the highest decline at the highest nitrogen level. In close analysis of the two potato varieties, the results indicated that same hill yields of B53 benefited more from the close intimacy than the Annette at low nitrogen levels. The results therefore, while underscoring the benefits of intimacy in exploiting the complimentary effects of the legumes, also indicates that the potato variety which stayed in the field longer even after harvest of the beans, gained relatively more. This is consistent with the idea that Nitrogen released from dead and decaying roots and root nodules may continue to benefit an accompanying intercrop.

1.0 INTRODUCTION

1.1 General Background

Intercropping involves growing two or more crops in the same piece of land in a season such that land use is maximized in terms of space and time dimensions (Andrew and Kassam 1976). It is the form of cropping system dominant in the humid and subhumid tropics due to the small farm sizes on which subsistence farming is practised.

Intercropping was previously considered primitive and disorderly farming practice which was to give way to sole cropping in order to enhance agricultural development. Recent trends, however, indicate resurged interest in this farming system. This could be due to the fact that researchers have been unable to provide the farmer with better alternatives based on sole cropping which can help in sustaining self sufficiency in food supply and at the same time maintain soil fertility (Osiru and Ezumah, 1987). Consequently farmers are not ready to abandon intercropping in favour of sole cropping (Barker, 1978). Norman (1978) after carrying out his surveys in West Africa reported that out of 24 different crops being grown in 174 different crop enterprises in one sample area of Northern Nigeria alone, less than 17% of these enterprises consisted of sole crops. In Kenya several crops are grown as intercrops with the common ones being maize/beans, maize/potatoes and sorghum/pigeon pea in drier areas. Potato/bean intercrop is a less common combination but is occasionally used in medium to high potential areas especially during the short rains. Both potato and beans perform better than maize in these areas (Kimani, 1987).

1.2 Importance of Intercropping

The observation that farmers in the tropics are not ready to abandon intercropping system in favour of sole crop shows how important it is in their lives. Merits of intercropping have been documented to include:- (i) increased efficiency in utilization of environmental resources by plants of different growth habits, growth cycles and even rooting systems (Andrew, 1972; Willey, 1979). The most important resources in this respect being radiation, mineral nutrient and water in the soil which have to be used efficiently due to increased cost of mineral fertilizers and irrigation. In the case of irrigation two or more crops would improve yield per unit of water used such that the overall water use efficiency is improved. (ii) with intercropping there is continuous provision of soil cover which reduces the amount of soil loss through water and wind erosion (Wrigley, 1969). This is most applicable in a case where the two or more crops growing together have different growth cycles such that at any given time there are some plants growing to provide soil cover. (iii) Evidence has it that when a grass crop is grown with a legume crop, the grass may benefit from the nitrogen fixed by the legume companion (Agboola and Fayemi, 1972; Trenbath, 1973; Faroda and Singh, 1983; Nadar, 1984; Cheminin'gwa and Nyabundi, 1994). This benefit is enhanced by increased proximity between the grass and the legume (Harris 1978; Cheminin'gwa and Nyabundi, 1994). (iv) With intercropping, Leihner (1983) reported that relatively small plots can be enough to provide the family with enough of the basic dietary requirements. In his work with cassava/bean intercrop, he found that one hectare of land can provide a balanced diet for about five adults for a whole year leaving a surplus of six tons of cassava for sale. The yield could still be doubled with improved technology which uses minimal input. (v) Intercropping has a higher productivity per unit area of land per unit time compared to growing the component species separately as indicated by Willey (1979) and Ikeorgu and Ezuma (1984). This high productivity could be as a result of efficiency in land use. Francis (1980) reported that in intercropping, land usage is improved by 10-40%. Ezumah *et al* (1987) also reported that land use efficiency increases as the crop mixtures become more and more complex from sole crop to 2, 3 or 4 crop mixtures. (vi) There is a more even distribution of labour in the case of intercropping, (Norman, 1978, Okigbo and Greenland, 1976).

1.3 Importance of Potatoes

Potato is a recent crop in Kenya but has already achieved a lot of popularity both in growing and non growing areas. In Kenya, potatoes are mainly grown in medium and high potential areas of Central and Rift Valley provinces as well as Kisii areas of Nyanza Province. The popularity could be arising from the fact that it is a high yielding crop giving upto 40 tons/ha within a short growing period. This means that with enough rains, upto three crops can be grown per year (Horton, 1987).

Nutritionally, potato provides carbohydrates which make about 70% of the tuber dry matter content. The tubers also contain high quality protein containing essential amino acids and substantial amounts of vitamins as well as minerals (Talbart and Burr 1975; Smith, 1977). Studies in Peru (CIP, 1984b) have shown that infants can get upto 80% of their protein requirements from potatoes and even a small quantity such as 100g of boiled potatoes supply upto

13% of the recommended daily protein allowance for children and upto 7% for adults. Sawyer (1978) reported that the food value of potatoes is very high and is only second to soybean and sugarcane in protein and calorie production per unit area respectively. Therefore potato grown by small scale farmers can help them to obtain a near balanced diet within their limited land sizes.

Economically potato contributes upto about 3% of the gross value of marketed agricultural production in Kenya (Anon 1979). The crop's industry also employs about 3% of the agricultural labour force in Kenya, (Durr and Lorenzl, 1980). Farmers grow potatoes mostly for home consumption and surplus is taken to the market. Durr and Lorenzl (1980) found that about 70% of the total potato production is used for subsistence and as seed the following season.

1.4 Importance of Beans

Field bean is an important crop in Kenya only second to maize as a food crop. It is grown extensively by small scale farmers in association with other crops such as maize, sorghum and ocassionally sugarcane. The greatest production comes from Eastern and Central provinces of Kenya. There are several varieties grown with the common ones being Mwezi moja, Canadian Wonder, Pink and Red Rosecoco. The average yield is , however low in the range of 220-670kg/ha although with good management practices the expected yield should be as high as 2500kg/ha (Acland, 1971). Nutritionally field beans like other crop legumes, is a good source of protein and high in essential amino acids.

1.5 Intercropping Potato and Beans

In Kenya the intercropping studies have largly concentrated on grass and legume crop mixtures (Fisher, 1979; Chui and Nadar, 1984; Cheminingwa and Nyabundi, 1994). According to survey by Durr and Lorenzl (1980), potato is principally grown as a sole crop and in a case of intercropping, it is commonly mixed with maize.

Potato and beans grow in almost the same agro-ecological zones but very little intercropping of the two has been practised. This could be because the two crops have similar growth habits, similar growth cycle and similar nature of the canopy formation, as such, they are likely to compete for the above and below ground resources within their environment. Such kind of competition can greatly affect the final yields. This sentiment was supported by Almeida (1976) who studied potato/bean mixtures in Brazil and reported that when the two are planted at a ratio of 70/30 population then good results were obtained but at a ratio of 50/50 population, total yields were depressed due to competition. According to Clarke and Shibles (1978) yield reduction occurs in a situation where the crops grown in association lack temporal separation in the growth cycle and physical differences such as height, leaf display and root volume which again is the case in potato bean mixtures. Similar growth habits can also bring management problems.

Potato bean intercrop can be a practical combination in a situation where advantage in space utilization is required (Leihner, 1983). Achievement of this advantage is possible because even if they compete for the same resources, the sum of inter specific competition is always less than the sum of intra-specific competition mainly because there is a possibility that the two species do not use the available resources at exactly the same extent and at exactly the same peak. According to Andrew (1972), in intimate crop mixtures, the effects of an intercrop are self compensating where a drop in growth rate or population of one crop allows the other to yield more such that the drop in overall yield is not very obvious, as such the two crops (potato and beans) can grow together and finally give the farmer some reasonable yield.

1.6 Justification of the Study

In Kenya potato and beans grow in the same agro ecological zones by the small scale farmers. Despite the small land size they have, farmers rarely intercrop the two. This study therefore intends to assess the possibility of obtaining yield advantage when potatoes and beans are intercropped under the limited farm sizes compared to sole crops.

Nitrogen is one of the most limiting nutrients in the soil which has to be replenished from time to time. Presently, the commercial fertilizers have become very expensive therefore alternatives have to be sought. Documented evidence shows that legumes are capable of fixing atmospheric nitrogen and some of it is excreted to the associate crop. Some of the nodules are also shed which decompose to release nitrogen (Agboola and Fayemi, 1972; Willey, 1979 and Chemininigwa and Nyabundi, 1994). Based on this argument, the study intends to find out whether increased intimacy of potato/bean intercrop would reduce the potato nitrogen requirement in form of fertilizer and hence reduce the cost of potato production for the small scale farmers who grow the two crops.

1.7 Objectives of the Study

(i) To study the effect of increased intimacy between potato and beans on growth and yield of the two crops.

(ii) Examine the interaction between planting patterns and nitrogen levels as reflected in growth and yield of the two crops.

(iii) To determine whether different potato varieties show significant differences in terms of association compatibility with beans as reflected in growth and yield of the two crops.

2.0 LITERATURE REVIEW

2.1 Effect of Intercropping on Crop Yield

One of the world's major problems is the need to increase food production especially in the tropics with high population growth rate. Several researchers dealing with intercropping have reported yield advantage when intercrops are compared with sole crops. Willey and Osiru (1972), working with sorghum-bean intercrop, observed a yield advantage of 64% when compared to sole crop of sorghum. Enyi (1972) studied mixtures of dwarf sorghum and beans at Morogoro, Tanzania and reported that the mixture gave 15% higher yields than pure stand. The same experiment repeated by Osiru (1972) in Uganda gave a yield advantage of 55% higher than sole crop of sorghum. The higher yields could be attributed to differences in resources utilization by the two crops growing together. This opinion was supported by Dewit (1960) who reasoned that yield advantage is much higher and much more detectable if the two crops growing in association use different environmental resources such that competition is low. Allen and Obura (1983) evaluating the merits of intercropping legumes with grasses in U.S.A. reported a land equivalent ratio as high as 1.27 and an area time equivalent ratio as high as 1.19. Taking an economic approach, Umaru *et al* (1984) reported up to 41% economic gain when cowpea was used as an intercrop with sorghum in India.

Further comparative studies by Fisher (1977a and b) to assess productivity and competition of maize/bean and maize/potatoes mixtures using alternate rows at different plant densities came up with the following conclusions:-

(i) Yields from intercrops are higher than sole crop under periods of high rainfall but fall short of pure stand yields in seasons of low rainfall.

(ii) The increased yield could be attributed to high population pressure in mixtures. The same argument was also used by Andrew (1972), in his sorghum bean intercrop planted at different plant densities.

There has been little work done in connection with potato intercropping. Kimani (1987) working in Kenya reported that both maize and beans intercropped with potato gave some yield advantage with more advantage being obtained from potato maize intercrop than potato bean intercrop. Liu and Midmore (1988) indicated in their work with potato maize intercrop that best results are obtained when maize is grown one month after the emergence of the potato plants mainly to avoid shading of the potatoes by the tall maize. He further noted that total productivity can only be marginally increased by choice of early maturing potato cultivars. Awoinke (1980) also observed improved yields of potato maize intercrops when planting time of maize was delayed to reduce the shading effect.

Subahn (1989) working with potato bean intercrop in Indonesia reported that higher yields are obtainable when beans are planted two weeks after emergence of potato plants than in the case of simultaneous planting. Oliveira (1990) noted in his work that when potato is grown in intercrop with beans, the ware potato yields are lower than in pure stands but seed tuber yields remain unaffected. This is mainly because shading tends to reduce tuber sizes. Bhiuya (1988) reported that modification of the planting arrangement affect the yields; working with potato wheat intercrop using different spacings of 40, 50, 60 and 70 cm between rows of potato and planting wheat in between each case, he noted that the greatest income equivalent ratio, can be achieved with potatoes planted 50cm between rows.

Despite the wealth of literature which show the benefits of intercropping, some researchers have reported gross yield reductions. Chui and Nadar (1984) found that beans grown with maize in alternate rows reduced maize yield by 33% mainly due to reduction in ear weight. From their work with maize and cowpeas, Nadar and Faught (1984) drew the conclusion that intercropping can lead to either yield reduction or yield increase depending on factors such as plant species, varieties being used, environmental condition under which the plants are growing as well as agronomic management being applied.

2.2. Effect of Spatial Arrangement on Growth and Yield of the Component Crops in the Intercrop.

Any two crops growing in close association must compete for the available resources. The intensity of competition depends on the extent of interaction of the two crop species. In intercropping spacing can be adjusted to create favourable condition for all the growing crops within the system. Freyman and Venkateswalu (1977) indicated in their work that allowing a wider spacing of 30cm between rows in sorghum legume mixture improved the yield of the legume. Singh *et al* (1973) and De and Mohta (1980) also reported the need for spacing adjustment. Their studies with soybean/maize intercrop gave results indicating that the double row spacing rather than single alternating rows of each species improved the yield of soybean without affecting the maize yield relative to the monocrop yield. Chui and Nadar (1984) studied the effect of spartial arrangement in maize/bean intercrop and reported 33% yield reduction when maize and beans were planted in alternate rows. He attributed the yield reduction to reduced ear size and ear weight. Their report further indicated that intercropping maize and beans by planting the two in the same hill without applied nitrogen fertilizer increased maize yield by 27% but bean yield was reduced by 67% mainly due to reduced plant growth and pod set of the shaded bean plants. The advantage of close association was also noted by Jaldin (1978) when he planted french bean maize intercrops in different associations and reported that planting the two in very close intimacies gave a land efficiency ratio based on total yields of between 30-50% more efficient than the monocrops. Nyambo et al., (1982) also reported significantly higher yields of cereals intercropped with legumes in same row than alternate rows.

Most crops show plasticity even when planted using very wide spacing such that the under population is compensated for. Mafra (1983) working on different possible spacings for sorghum reported that sorghum planted at a wider spacing of 90cm between rows showed up to 97% yield recovery due to their increased tiller numbers and increased head sizes.

Apart from improved yield, there are others beneficial effects of intercropping. Radke (1988) reported that when soybean is grown between two rows of corn, the corn plants act as temporary wind brakes sheltering them from the effect of wind.

Some researchers on potato maize, intercrop in San Ramon South America reported that at a spacing of 1x1.4m with the two grown in alternate rows, gave yield advantage measured as land equivalent ratio (LER) of 1.63. This high value was attributed to the shading effect of maize which created favorable microclimate for the potatoes growing underneath CIP (1984b). According to CIP (1981) report, some experiments carried out indicated that potato grown in association with others crops suffered yield reduction mainly due to reduced tuber size without any significant change in the number of tubers.

Kimani (1987) in Kenya carried out some studies to compare yield advantages of potato maize and potato bean intercrops with their respective sole crops and reported a yield advantage of 1.97 and 1.77 respectively for the two mixtures. He further noted that potato maize mixture has a better association compatibility than potato/bean mainly due to the differences in agronomic characteristics such as growth habit, growth cycle and rooting depth as well as total root volume.

2.3 Nitrogen Sources, Uptake and Utilization by Plants

The major forms of soil nitrogen are:- (i) organic nitrogen which occurs in form of amino acids and comprises about 90% of the soil nitrogen (ii) Ammonium nitrogen fixed by certain clay minerals (iii) Soluble inorganic ammonium and nitrate compounds which make upto about 2% of total soil nitrogen Salisbury and Ross (1986). Variability in these percentages may occur where large quantities of inorganic fertilizer or manure have been applied frequently Brady (1984).

Plants utilize nitrogen in the form of nitrates (NO_3^-) or ammonium ions (NH_4^+) which can be applied directly or obtained through mineralization of the organic matter. Most plants absorb nitrogen in the form of (NO_3^-) ions unless certain environmental conditions such as acidic environment occurs, causing the persistence of NH_4^+ ions since nitrification cannot take place, then plants take NH_4^+ ions. The (NO_3^-) ions taken have to undergo reduction process inside the plant before being utilized. The whole process requires energy in form of ATP and NADPH as well as nitrate and nitrite reductase enzymes (Salisbury and Ross 1986). The NH_4^+ ions formed in the reduction process are then converted to amino acids and amides to be used in protein synthesis.

Mineralization of organic matter plays an important role in supplying inorganic nitrogen to the crops. The first step in mineralization is the conversion of organic nitrogen to NH_4^+ ions by heterotrophic soil bacteria in the process called aminonification. Under conditions of near neutral pH, the NH_4^+ ions are oxidized to (NO^-_3) ions within a few days in the process of nitrification which occurs in two steps. First step involve conversion of ammonia to nitrite by *Nitrosomonas* bacteria followed by the second step involving conversion of nitrite to nitrate by *Nitrobactor* bacteria (Tisdale, 1966; Salisbury and Ross, 1986). In acidic soils there is lack of nitrifying bacteria and the common form of nitrogen is NH_4^+ ions and plants growing in such environments show preference to NH_4^+ ions and may show intolerance to NO_3 ion forms of nitrogen (Pate and Farquhar, 1988).

Nitrogen is the major component for protein enzymes, coenzymes, bases and other physiological structures in the body of living organisms (Mengel and Kirkby, 1979). With reduced nitrogen supply to growing plants, there would be low chlorophyll and enzyme formation which in turn affects photosynthetic activities, the important determinant in plant growth and development. As a result, the plant remains stunted and the leaves turn yellow. Milthorpe (1974) emphasized that leaf size is determined by cell expansion, which is influenced by nutrient supply, the main one being nitrogen.

2.4 Importance of Legumes in Nitrogen Fixation

Nitrogen fixation involve reducing free nitrogen(N_2) to NH_4^+. It is carried out by certain prokaryotic microorganisms in symbiotic association with legumes and also by certain free living bacteria and blue green algae, but the symbiotic fixation is the most important in agriculture. The main bacteria species involved in nitrogen fixation is the *Rhizobium* species. Each legume species has a specific *Rhizobim* strain with which it associates, for purpose of N fixation (Salisbury and Ross, 1986). The Rhizobium persists in the soil saprophytically until it comes into contact with the right legume species and infect the root hair or the damaged epithelial cells. Once inside it divides to give bacteriods and stimulate the cells to divide and form mature nodules complete with the vascular tissue which is continuous with those of the roots (Graham, 1972; Salisbury and Ross, 1986). The bacteriods obtain their carbohydrate requirement from the host plant and some of their fixed nitrogen is utilized by the host plant.

Under favourable soil and environmental conditions, the nitrogen fixed biologically reach 3.5 million metric tons globally per year (Brady, 1984). With the increasing cost of commercial fertilizer, some of this could be trapped to benefit any crop grown in association with the legume. Furthermore, legumes tend to release their nitrogen faster in decomposition due to their low C:N ratio therefore can be used effectively as green manure (Srivastava, 1982). The beneficial effect of legume was also supported by Singh *et al* (1986) when they intercropped maize with green grams and soybean and reported that the NO_3^- and NH_4^+ ions concentration was higher and bacterial activity responsible for nitrification was also higher than in sole crop of maize. In his report, maize yield also increased by between 15 and 20% and grain protein content increased by 20% under intercropping.

The fixed nitrogen is important even to a succeeding crop as was observed by Balyan and Seth (1985) that the wheat suceeding cowpea/maize intercrop gave better yields than wheat succeeding another cereal. They attributed the better yield results to the residual effect of nitrogen fixed by the cowpea earlier. The same opinion was also expressed by Feroda and Singh (1983), who carried out a study on the effect of preceding crop on the nitrogen need on succeeding wheat and found that the grain yield was maximum when a crop of black gram was followed by green gram and then cowpea before wheat. This ensured accumulation of fixed nitrogen which was then utilized by the succeeding wheat crop.

Legumes grown under intercropping situation have also been reported to increase the rhizosphere bacterial count. Wahua (1984) working with maize/cowpea/melon intercrop hinted that rhizosphere bacterial count was more in an intercrop situation than in cases where melon or maize was grown as a sole crop. This could help in organic matter decomposition and hence fertility improvement without necessarily adding mineral fertilizers.

2.5 Effect of Nitrogen on Growth and Yield of Component Intercrops

Under intercropping, there is competition for various plant resources. To reduce competition, enough nutrients should be applied. Under intercropping system even legumes may require an external source of nitrogen because shading reduces nodulation. Osiru and Willey (1972) suggested that in a case where cereals are intercropped with the legume, some nitrogen should be applied to the cereal to help moderate competition. Adelitoye (1980) working with maize/cowpea intercrop further confirmed an increase in maize yield with increased nitrogen levels from 0-90 kg/ha with a steady decrease in cowpea yield which they attributed to the shading effect from the vigorously growing maize plants as the nitrogen levels increased. The increased nitrogen levels also reduced the nodulation by cowpea and hence very little nitrogen fixation occurred. Hasterman (1980) indicated that legumes are capable of fixing large quantities of nitrogen and contribute some to companion crop but under high levels of fertilizer nitrogen, nodulation and nitrogen fixation reduced drastically. He noted that by increasing nitrogen levels from 56-168 kg/ha, the proportion of nitrogen derived from legume companion reduced from 44% to 10% in whole corn plants and from 57% to 23% in the grains.

2.6 Effect of Nitrogen on Growth and Performance of Potato Sole Crop

Potato is a heavy feeding crop which requires large supply of both macro and micro nutrients essential for proper growth and development. Studies have shown that actively growing potato crop can utilize upto 4 kg/ha of nitrogen per day together with phosphorus and potassium (Tanner and Anderson 1976). Tubers act as the major sinks absorbing large quantities of the minerals. This explains why nitrogen deficiency affects the marketable size of potatoes.

Nitrogen is a constituent of chlorophyll and promotes cell division, photosynthesis and haulm growth (Burton, 1966). In potato production large quantities of available nitrogen increases the leaf area index (LAI) from early stages and hence total biomas is also higher (Humphries and French 1963). With increased leaf area which is the photosynthetic source, the number of tubers and tuber size will also be greater and the final yield higher than if no nitrogen is used. Holler (1975) working with potato in Kenya found that with nitrogen rates increased from 0-150 kg/ha, the tuber yields increased as well as the nitrogen content in the leaves and the tubers.

In fertilizer application, it is important to note that although fertilizer increases yield, there is a point beyond which it may have adverse effect on yield. Report by Morby and Milthorpe (1975) and Morby (1978) indicated that there is an optimum level of nitrogen beyond which vegetative growth increases at the expense of tuberization causing delayed tuber initiation, maturity and low dry matter yields in the tubers. According to Smith (1968) high nitrogen application just before blossoming retard tuber formation while late application delay maturity and the tubers obtained have poor storage qualities.

The form of nitrogen applied affect plant function to some extent. In India, Cooke (1973) found that nitrogen applied in slowly available forms (sulphur coated urea) allowed tubers to form earlier than when the ready source of nitrogen (ammonium nitrate) was used. This is because with sulphur coated urea there is moderate, steady supply of nitrogen used for continuous growth and development unlike ammonium nitrate which releases its nitrogen rapidly causing too much vegetation regrowth. Hendrickson *et al* (1978) also observed that with continuous supply of nitrogen in the form of Ammonium ions instead of nitrate ions normal metabolism is interfered with which lead to impaired development and hence reduced yields.

Method of fertilizer application may also be important. Fecenko (1988) indicated that an average potato requires 120 kgN/ha but when he applied 90 kg/ha at planting followed by 30 kg/ha at flowering, he obtained better yields and higher dry matter content than when 120 kg/ha was applied all at once or in 3 splits of 40 kgN/ha each. In general, high nitrogen rates used have no effect on tuber total or reducing sugar content but reduces the chip and crisp quality of potatoes (Kabira, 1983; Smith, 1968; Harris, 1978).

2.7 Effect of Nitrogen on Growth and Performance of Legumes

Legumes are capable of fixing large quantities of atmospheric nitrogen through the root- *Rhizobium* symbiotic association and the effective nodulation depends on the availability of correct legume and bacterial strain as indicated by Keya *et al* (1982) as well as the presence of organic matter and suitable environment.

Several experiments have shown both inhibitory and supplementary effects of added nitrogen on legume growth and yield. Agboola and Fayemi (1972) reported significant cow pea yield increase when 20 kgN/ha was added to the soils containing about

1% organic matter. Marrero and Guzmand (1986) also noted that to obtain maximum yield of beans there is need to add 20 kgN/ha to act as starter nitrogen before full nodulation is achieved in soils low in nitrogen.

A number of researchers such as Lawn and Brun (1974) Herridge (1982) and Chui (1988) have reported reduced nodulation when nitrogen is applied in high rates. This could be because the applied nitrogen is readily available therefore no need to fix the excess nitrogen. Lawn and Brun (1974) further noted that in soybeans fresh root nodules reduced when nitrogen rates were increased from 224 kg/ha to 448 kg/ha. Eaglesham *et al* (1982) in the investigation of the effect of nitrogen on nodule formation and development in legumes concluded that high level nitrogen applied on the soil had long term effect on nodule formation and development in cow pea crop. In situations where high amounts of nitrogen was applied in the soil, the nodulation process remained low for a long time. Excess N also leads to proneness to lodging, diseases and delayed maturity

On the contrary some researchers have reported adverse yield reductions due to lack of nitrogen. Barke (1978) indicated that shortage of nitrogen during pod and seed development stages resulted in pod abortion, lower quality seeds and hence low final yields.

Although legumes fix their own nitrogen, starter nitrogen of about 20 kg N/ha should be applied to give the plants early rapid growth. This rate applies in the tropics where soil environment favour nodulation. In temperate areas, soil *Rhizobium* strains may be lacking or may exist in very low populations and in such cases legumes may require even upto 100 kgN/ha of combined nitrogen as indicated by Olufayo (1980) who carried out his studies in the temperate areas of the United States. Awonaike *et al* (1980) reported that it should not be taken in general that increased nitrogen application affect nodulation of field beans because according to his work, there are certain varieties and strains of inoculant which respond positively to increased nitrogen levels reflected in increase in dry matter accumulation. Similar observation was made by Westermann *et al* (1981) who carried out an experiment on nitrogen source on bean seed production and concluded that there is interaction between cultivar and nitrogen fertilization where some cultivars are more sensitive to nitrogen fertilization than others giving differences in fertilizer application requirement Asif and Greig, (1972) also reported an interaction between nitrogen, phsphorus and potassium fertilizers with respect to yield and nutrient content of snap beans.

2.8 Assessment of Yield Advantage in Intercropping

The major methods used in assessing yield advantage include:- The relative coefficient (De Wit, 1960), competitive Index (Donald, 1963), and Land Equivalent Ratio (LER) (IRRI, 1974 and 1975). Of the above methods, land equivalent ratio has become the most commonly used mainly because it is a simpler concept and easier to understand and interpret. LER is defined as relative land area under sole crop that is required to produce the yields achieved by intercropping under same management (IRRI, 1974). LER can be used to measure yield advantage and disadvantage. LER value greater than unity indicates yield advantage whereas unity and less than unity indicate no advantage and disadvantage respectively. The LER can also be used to determine the biological efficiency achieved by intercropping.

Despite its wide usage, LER has the following limitations:- (i) being defined as a ratio it can give values which are not comparable at a given scale for sole crop and intercrops, as such only absolute yield figures are used (Mead and Willey, 1980); Stainer, 1982). (ii) LER measures the proportion of two or more crops on assumption that the harvested portions of the two crops are exactly those that are required in each situation (Mead and Willey, 1980). Therefore, It may bear little relationship to total yield since it tends to over rate the contribution of the yielding component. For the several methods used in yield assessment it is important to consider the following points:-

(i) Whichever method is used, yield assessment of different crops cannot be compared directly with each other (Stainer, 1982 and Beets 1982) and productivity can only be assessed by using a common denominator (Willey, 1979 and Hilderband, 1976).

(ii) Farmers objective must also be known in the assessment.

(iii) In the comparison, the management applied to sole crop should be similar to that applied to intercrop and the plant populations maintained at their optimum (Huxley and Maingu 1978; Stainer 1982).

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was conducted at the University of Nairobi's Faculty of Agriculture Field Station, Kabete. The station co-ordinates are 2^{o} 15' South and 36^{o} 44' East with an altitude of 1,850 m above sea level. The soil was well drained very deep, dark reddish brown to dark red friable clay with acid humid top soils (humic NITOSOLS) developed from Limuru Trachyte (Michieka, 1977). The area receives bimodal rainfall of about 1000 mm p.a. distributed in two seasons; long rains from March to June and short rains from October to December. The mean monthly temperature has a minimum of 12^{o}C and maximum 23^{o}C (Anon, 1985).

The experiment was carried out in two seasons. First experiment during the short rains of October to December 1993 and the second experiment during the long rains of May to August 1994. The soil nitrogen content at planting measured using the Kjedhal method was 0.29% and 0.24% in the first and second seasons respectively

3.2 Experimental Design and Treatments

Both experiments had a 2 x 4 x 4 factorial structure laid out in a completely randomised block design and replicated three (3) times. The treatments consisted of two potato varieties; Annette (V_1), an early variety which matures in 2$^1/_2$-3 months and B53 (V_2), a late variety which matures in 3$^1/_2$ - 4 months, four nitrogen levels of 0kg/ha (N_1); 37.5kg/ha (N_2); 75kg/ha (N_3), and 112.5kg/ha (N_4), together with the four planting patterns of sole

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There were a total of 48 treatments per block with each treatment plot measuring 5.25 x 4m. GLP-2 (large Rosecoco). On assumption that the farmer's main crop was potato with beans being a supplementary crop, the potato spacing was maintained at the monocrop level of 75x30cm giving a plant population of 44,444 plants/ha, and about 93 plants per plot. The beans therefore formed additional crop. In the case of alternate hill treatment the bean hills were planted midway between two neighbouring potato plants within the row. Beans for alternate row were planted halfway between two potato rows. To give a constant plant population, the beans in the sole crop were also planted using the same spacing of 75x30cm.

3.3 Crop Husbandry

The land was ploughed and harrowed twice to obtain a suitable tilth. Phosphorous was applied in form of Triple superphosphate (0:46:0) broadcasted uniformly within the potato and bean planting furrows at the rate of 15kg/haP and mixed thoroughly with the first 15cm of soil. The nitrogen fertilizer treatment was applied inform of Calcium Ammonium Nitrate (CAN) at planting time. Two bean plants and one chitted potato tuber were planted per hill after applying aldrin 40% to control cutworm and Furadan 5G to control nematodes.

Spraying against early and late potato blight, was done using Dithane M45 in season one and Milraz in season two. Dithane M45 was replaced with Milraz in season two because it was cold and hummid leading to a more serious blight attack. Bean fly in beans and potato fly were controlled using Dimethoate insecticide. First weed control was done after about one month followed by earthing up of the potato plants three weeks latter, both activities were done manually.

3.4 Measurements and Observations

The parameters of study included: biomas accumulation, yield and yield components of both crops and nodule numbers and weights of beans.

3.4.1 Biomas accumulation

The first sampling was done four weeks after emergence and then after every fortnight until harvesting time for both beans and potatoes. A total of three samplings were done in season one and four in season two. The sampling was done in a stratified and sequential manner starting with outer rows so that the inner rows were left for final harvest. Five plants were harvested each time for use in determination of above ground biomass. Sampled plant were cut at ground level, washed to remove soil and dirt and dried to constant weight at $80^{0}C$ for 48 hours.

3.4.2 Tuber Yield and Yield components

At maturity two inner rows of potato were harvested and the yield components determined as (i) number of tubers per plant (ii) Fresh tuber yield (tonnes/ha).

3.4.3 Bean Yield and Yield components

About 30 plants were harvested from the inner rows and used to determine yield per hectare, number of pods per plant and seeds per pod.

3.4.4 Nodule Numbers and Weight

The number of nodules and nodule weight was determined by counting nodules from two plants per plot at each biomass harvest Roots of bean plants which had been harvested for biomers determination were carefully lifted to reveal the nodules. The latter were counted then picked and dried at 80°C for 48 hours.

3.4.5 Land Equivalent Ratio

After determining yield in tonnes/ha for the sole crop and the intercrops, the land equivalent ratios were calculated as described by Willey (1972) which can be summarized mathematically as:-

$$LER = \frac{\text{Intercrop yield of potato}}{\text{Sole crop yield of potato}} + \frac{\text{Intercrop yield of beans}}{\text{Sole crop yield of beans}}$$

The sole crop was compared with all forms of intercropping over the two seasons.

3.4.6 Laboratory work

Soil tests were done prio to planting in both seasons for the following:- pH, Ca, N, %C, K, Na, Ca, Mg and P and the results are given on appendix A.

3.5 Data Analysis

Analysis of variance (ANOVA) was computed for each of the parameters and mean separation done using Duncan's Multiple range test where F test was significant as described by Steel and Torrie (1980) and Cochran and Cox (1957).

4.0 RESULTS

4.1 (SEASON ONE, NOVEMBER - MARCH 1993)

4.1.1.: General Management

Plant emergence four weeks after planting averaged 85% for Annette potato variety, 71% for B53 potato variety and 89% for beans. However gapping was done within the first week of emergence for both potato and beans to improve on the plant population. With irrigation facilities available and making use of already chitted potato seeds, the gapped plants managed to catch up with the already well established fast growing potato and beans plants.

The weather became dry at the end of December (Appendix A) and the crop was irrigated to avoid water stress.

There was no serious disease problem except a mild attack of late blight in potatoes. The attack appeared to be more on Annette than on B53 leaves. There was incidence of two insect pests namely green peach Aphids (*myzus persicae*). and white flies (*Bermissia tabacum*) during the dry weather but they were rapidly controlled through irrigation and application of insecticides.

4.1.2: Effect of planting patterns and nitrogen levels on dry matter of potato plants:

In terms of dry matter yield Annette and B53 potato varieties as indicated in tables 1a and 2a only responded favourably to nitrogen at the highest level (112.5kg/ha) in both 4 and 6 weeks after emergence with the lowest yield realised at 0kg/haN at 4 weeks after emergence. There were no interactions at the two sampling stages, however after 8 weeks, some interaction between nitrogen application and planting patterns emerged particularly at the low nitrogen levels of 0kg/ha and 37.5kg/ha, sole potato and potato with beans in the same hill were similar but higher than potato and beans planted in alternate rows and alternate hills within the same row. As the nitrogen levels were increased to 75kg/ha and 112.5kg/ha the sole crop in terms of dry matter yielded higher than the three planting patterns which were not different on the other hand dry matter response to nitrogen showed that sole crop behaved the same at 0kg/ha and 37.5kg/ha and also at 75kg/ha and 112.5kg/ha but dry matte at 0 and 37.5kg/ha were significantly lower. The same trend was observed in the alternate hill planting pattern. Alternate row planting gave the lowest dry matter yield without nitrogen however at 37.5kg/ha and 75kg/ha the response observed similar at the application of 75kg/ha and 112.5kg/ha. In same hill planting response to nitrogen levels of 0 and 37.5kg/ha were not different. Similarly, the response to 75kg/ha and 112.5kg/ha were also the same, however it was noted that the response to lower levels of N, 0 and 37.5kg/ha in this particular planting pattern was much better than that from higher nitrogen levels of 75kg/ha and 112.5kg/ha.

In the B53 potato variety, there was no significant effect of planting pattern or nitrogen at 4 and 6 weeks after emergence (tables 1b and 2b). The main effects and the interactions were significant at 8 weeks after emergence, where at the low nitrogen levels of 0kg/ha and 37.5kg/ha the same hill planting pattern had the highest dry matter yield compared to the rest of the patterns whose dry matter values were similar. At the nitrogen levels of 75kg/ha and 112.5/kg/ha the sole crop dry matter yield was higher than yields of all the other planting patterns. Alternate row and same hill intercropping were statistically similar at 75kgN/ha but alternate row was statistically superior to alternate hill and same hill arrangements at 112.5kg/ha. The dry matter response to nitrogen was such that in sole crop, the yield at 112.5kg/ha was significantly higher than at all the other three levels of 0, 37.5 and 75kg/ha. The yields at 0 and 37.5kg/ha were statistically similar but lower than the yields at 75kg/ha. Alternate row yields behaved the same at 0 and 37.5kg/ha as well as at 75 and 112.5kg/ha. The yields at 0kg/ha and 37.5kg/ha were significantly inferior to the yields obtained at 75 and 112.5kg/ha. The alternate hill yields were statistically similar at 0, 37.5 and 112.5kgN/ha and at 0, 37.5 and 75kgN/ha. The nitrogen levels applied had no significant effect on same hill planting pattern as the dry matter values were statistically similar (Table 3b).

The two potato varieties were different with Annette giving significantly higher dry matter yields than variety B53 at the third sampling.

Table I: Effect of planting patterns and nitrogen levels on dry mater (kg/ha) yield of (a) Annette and (b) B53 season one potato varieties 4 weeks after emergence (Season one)

(a)

Planting Patterns	Nitrogen levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP1	275.78	358.37	374.81	479.48	372.1
PP2	263.56	345.33	377.96	409.52	348.9
PP3	284.22	340.22	309.41	450.52	333.6
PP4	280.67	389.63	370.37	519.93	389.2
N Means	263.60_z	358.41_y	357.89_y	463.90_x	

CV = 6%

(b)

Planting Patterns	Nitrogen levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP_1	234.41	293.85	363.63	304.92	299.20
PP_2	278.96	252.00	301.04	317.11	287.28
PP_3	238.96	229.92	349.85	387.55	301.57
PP_4	269.03	287.11	305.26	357.55	304.74
N Means	255.34	265.49	329.95	341.78	

Within each column, means followed by the same superscript(s) (a,b,c,d) and within each row, means followed by the same subscripts (x,y,z), are not significantly different at 5% probability level, according to Duncans Multiple Range test

		V_1	V_2
Variety means		287.49	272.57
F test	V		
	ns		

Table 2: Effect of planting patterns and nitrogen levels on dry matter (kg/ha) yield of (a) Annette and (b) B53 Potato varieties 6 weeks after emergence (Season one)

(a)

Planting Pattern	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP_1	315.33	384.37	321.63	362.59	345.98
PP_2	356.96	406.67	397.11	409.32	392.52
PP_3	340.59	347.56	383.30	444.80	379.56
PP_4	345.04	383.18	337.78	420.81	371.70
N Means	339.48_{xy}	380.45_{xy}	405.00_{xy}	408.75_{x}	

CV = 13%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP_1	289.34	318.22	365.33	326.73	324.91
PP_2	334.09	377.77	407.33	333.48	363.17
PP_3	340.82	362.22	412.29	396.96	378.73
PP_4	330.04	360.22	403.04	340.37	358.42
N means	323.57	354.61	397.00	349.39	

CV = 15%

Within each column means followed by the same superscript (a,b,c) and within each row means followed by the same subscript (x, y, z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	380.44	356.31

F test V

*

Table 3: Effect of planting patterns and nitrogen levels on dry matter (kg/ha) yield of (a) Annette and (b) B53 Potato varieties 8 weeks after emergence (Season one)

(a)

Planting Pattern	Nitrogen levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP_1	791.63^{a}_{y}	834.44^{a}_{y}	1038.43^{a}_{x}	1123.47^{a}_{x}	946.99^{a}
PP_2	394.52^{b}_{z}	587.92^{b}_{y}	655.92^{b}_{xy}	706.59^{b}_{x}	586.24^{b}
PP_3	287.85^{b}_{y}	350.67^{b}_{y}	605.56^{b}_{x}	559.41^{b}_{x}	450.87^{c}
PP_4	734.63^{a}_{x}	791.48^{a}_{x}	552.59^{b}_{y}	549.26^{b}_{y}	656.99^{b}
N Means	552.16_{y}	641.13_{x}	713.13_{x}	734.93_{x}	

CV = 8%

(b)

Planting Pattern	Nitrogen levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP Means
PP_1	405.33^{b}_{z}	363.93^{b}_{z}	758.00^{a}_{y}	873.00^{a}_{x}	600.07^{a}
PP_2	374.96^{b}_{y}	359.93^{b}_{y}	462.81^{b}_{x}	528.52^{b}_{x}	431.56^{b}
PP_3	367.70^{b}_{xy}	352.89^{b}_{xy}	321.41^{c}_{y}	401.63^{c}_{x}	360.91^{c}
PP_4	486.22^{a}_{x}	464.67^{a}_{x}	431.62^{b}_{x}	411.85^{c}_{x}	448.59^{b}
N Means	408.55_{y}	385.36_{y}	493.46_{x}	553.75_{x}	

CV = 9%

Within each column means followed by the same superscript (a,b,c,) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	654.02	460.28

F test V
**

4.1.3.: Effect of planting patterns and nitrogen levels on dry matter yield of bean plants

Bean intercropped with Annette potato variety showed nitrogen effects as being significant, however there were no significant interactions at four weeks after emergence (tables 4a, b). The low nitrogen level of 0 kg/ha gave the lowest dry matter yield but was similar to yields obtained at 37.0 kg/ha and 112/.5kg/ha nitrogen level. The three nitrogen levels of 37.5, 75.0 and 112.5kg/ha also behaved the same (Table 4a). At six weeks after emergence the main factors of nitrogen and planting pattern and their interactions were significant. At the low nitrogen level of 0 kg/ha, the sole crop beans and beans planted in alternate rows realised same dry matter values that were significantly higher than those of beans intercropped in alternate hills and same hill, but the latter two intercropping patterns were not significantly different from each other. The dry matter yield values obtained when 37.5 kg/ha of nitrogen was applied were similar for all the planting patterns. Also at 75-kg N/ha, the biomass of sole crop, alternate row and alternate hills were statistically similar, except in sole crop, dry matter yield was significantly higher than that of beans intercropped in the same hill with Annette. The highest nitrogen level of 112.5 kg/ha yieled the same in sole, alternate row and alternate hill cropping patterns. The same applied to same hill and alternate hill In this study a pattern developed where by low nitrogen levels of 0 kg/ha and 37.5 kg/ha dry matter yields that were not significantly different but were lower than the dry matter yield obtained by high application of 75 kg/ha and 112.5 kg/ha nitrogen. In sole beans and same hill intercropping, the dry matter yields at 75kg/ha and 112.5 kg/ha nitrogen were the same for all the planting patterns (Table 5a). The third sampling done at eight weeks after emergence also gave the main effects as well as their interactions were statistically similar (Table 6a). Under nitrogen levels of 0 kg/ha and 37.5 kg/ha, all the four planting patterns were similar but when the nitrogen level was increased to 75kg/ha, sole crop beans yielded higher than the three planting. At 112.5kg sole crop yields and those from alternate rows were statistically similar but were significantly higher than yields from alternate hill and same hill patterns. The two planting patterns of same hill and alternate hill were also not different. Beans planted as sole crop and in alternate rows only showed a significant increase in biomass with N application of 75kg/ha and 112.5kg/ha respectively. Beans planted in same hill and alternate hills placements did not respond to nitrogen application.

In terms of crop biomass accumilation at fourth week after planting, intercropping beans with B53 potato variety responded to nitrogen significantly but not the interactions (Table 4b). The application of 0 kg/ha gave dry matter yields significantly lower than for 37.5 kg/ha and 112.5 kg/ha but statistically similar to dry matter yields obtained by application of 75 kg/ha. The dry matter yields obtained by application of 37.5 kg/ha, 75 kg/ha and 112.5kg/ha were not significantly different. The second sampling done at 6 weeks after emergence gave both the main effects and the interactions were significant. Application of 0kg/ha and 112.5kgN/ha, sole crop and alternate row planting were statistically similar and higher than alternate hill and same hill planting, however the latter two patterns were statistically similar. Application of 75kg/ha nitrogen, sole crop yields as was significantly higher than those of the other three planting for all the planting patterns (Table 5a). The third sampling done at eight weeks after emergence also gave the main effects as well as their interactions were statistically similar (Table 6a) Under nitrogen levels of 0 kg/ha and 37.5 kg/ha, all the four planting patterns were similar but when the nitrogen level was increased to 75kg/ha, sole crop beans yielded higher than the three planting. At 112.5kg sole crop yields and those from alternate rows were statistically similar but were significantly higher than yields from alternate hill and same hill patterns. The two planting patterns of same hill and alternate hill were also not different. Beans planted as sole crop and in alternate rows only showed a significant increase in biomass with N application of 75kg/ha and 112.5kg/ha respectively. Beans planted in same hill and alternate hills placements did not respond to nitrogen application.

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The response of different planting patterns to nitrogen was such that the patterns; alternate row, alternate hill and same hill the first two nitrogen levels of 0 kg/ha, 37.5 kg/ha showed no differences but lower than dry matter yields obtained when 75 and 112.5 kg/ha was applied in the latter two patterns of same hill and alternate hills. At eight weeks after emergence both planting patterns and nitrogen effects as well as their interactions were significant (Table 6b). Under low nitrogen level of 0 kg/ha, sole crop out-performed the other planting patterns, of same hill and alternate hill and alternate row. The first two patterns were also different however, with application of higher nitrogen quantities of 37.5 kg/ha, 75 kg/ha, and 112.5 kg/ha sole crop and alternate row yields were statistically the same higher than the yields in alternate hill and same hill planting arrangements. In all planting patterns, only application of 112.5 kgN/ha significantly increased bean biomass (Table 6b). Throughout the sampling, varietal differences were not significant, except at week 8 where bean/B53 intercrop had significantly higher dry matter yield.

Table 4: Effects of planting patterns and nitrogen levels on bean dry matter yield (kg/ha) when intercropped with (a) Annette and (b) B53 potato varieties at 4 weeks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (kgN/ha)				
	N1	N2	N3	N4	PP Means
PP1	458.84	522.67	509.67	500.30	497.25^{a}
PP2	480.92	534.60	552.16	508.73	519.1^{a}
PP3	450.12	474.23	499.80	504.73	481.75^{a}
PP4	474.13	501.83	522.97	501.57	500.13^{a}
N Mean	466.00$_{y}$	508.33$_{xy}$	521.65x	503.83$_{xy}$	

CV = 13%

(b)

Planting patterns	Nitrogen levels (kgN/ha)				
	N1	N2	N3	N4	PP Means
PP1	506.27	554.27	509.96	598.03	542.13
PP2	461.27	521.47	516.47	508.00	501.80
PP3	454.39	494.00	493.60	547.57	512.39
PP4	451.69	548.27	459.87	501.03	490.21
N Mean	468.91$_{y}$	529.50$_{x}$	495.0$_{xy}$	528.66$_{x}$	

CV = 12%

Within each column means followed by the same superscript(s) (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	508.58	509.76

F test V
ns

Table 5: Effect of planting patterns and nitrogen levels on bean dry matter yield intercropped with (a) Annette and (b) B53 potato varieties at 6 weeks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (kgN/ha)				PP Means
	N1	N2	N3	N4	
PP1	913.97^{a}_{xy}	830.10^{a}_{y}	1105.23^{a}_{x}	1183.73^{a}_{x}	1008.26^{a}
PP2	757.50^{a}_{y}	654.07^{a}_{y}	1009.31^{a}_{x}	1021.33^{ab}_{x}	860.55^{ab}
PP3	563.17^{b}_{y}	758.43^{a}_{y}	1009.87^{a}_{x}	1085.73^{a}_{x}	$844.23a^{b}$
PP4	555.20^{b}_{y}	743.13^{a}_{xy}	802.2^{b}_{x}	864.30^{b}_{x}	766.21^{b}
N means	697.46_{y}	746.43_{y}	981.65_{x}	1038.77_{x}	

CV = 10%

(b)

Planting patterns	Nitrogen levels (kgN/ha)				PP
	N1	N2	N3	N4	
PP1	869.23^{a}_{y}	1176.10^{a}_{x}	1132.93^{a}_{x}	1132.70^{a}_{x}	1077.74^{a}
PP2	847.73^{a}_{y}	875.33^{b}_{y}	847.37^{b}_{y}	1130.76^{a}_{x}	925.29^{b}
PP3	626.07^{b}_{y}	686.20^{c}_{y}	933.20^{b}_{x}	994.07^{b}_{x}	809.89^{c}
PP4	692.80^{b}_{y}	680.20^{c}_{y}	885.03^{b}_{x}	947.3^{b}_{x}	801.33^{c}
N means	758.96_{z}	854.46_{yz}	$949.63y$	1051.21_{x}	

CV = 8%

Within each column means followed by the same superscript (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	869.81	903.56

F test V

ns

Table 6: Effect of planting pattern and nitrogen levels on bean dry matter yield (kg/ha) when intercropped with (a) Annette and (b) B53 potato varieties at 8 weeks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (kgN/ha)				
	N1	N2	N3	N4	pp means
PP1	$1010.08^{a}{}_{y}$	$1021.35^{a}{}_{y}$	$1640.93^{a}{}_{x}$	$1687.70^{a}{}_{x}$	1340.02^{a}
PP2	$1220.37^{a}{}_{y}$	$1079.40^{a}{}_{y}$	$1287.18^{b}{}_{y}$	$1758.43^{a}{}_{x}$	1336.35^{a}
PP3	$1034.59^{a}{}_{x}$	$1161.26^{a}{}_{x}$	$1188.30^{b}{}_{x}$	$1095.78^{b}{}_{x}$	1119.98^{b}
PP4	$1031.26^{a}{}_{x}$	$1174.75^{a}{}_{x}$	$1176.43^{b}{}_{x}$	$1060.60^{b}{}_{x}$	1110.76^{b}
N means	1074.07_{y}	1109.19_{y}	1179.21_{y}	1400.63_{x}	

CV = 5%

(b)

Planting patterns	Nitrogen levels (kgN/ha)				
	N1	N2	N3	N4	PP means
PP1	$1509.17^{a}{}_{y}$	$1388.90^{a}{}_{y}$	$1574.57^{a}{}_{y}$	$2100.30^{a}{}_{x}$	1643.24^{a}
PP2	$1321.78^{b}{}_{y}$	$1347.27^{a}{}_{y}$	$1444.06^{a}{}_{y}$	$2246.43^{a}{}_{x}$	1589.89^{a}
PP3	$067.71^{c}{}_{y}$	$1006.15^{b}{}_{y}$	$1240.06^{b}{}_{y}$	$1806.43^{b}{}_{x}$	1280.09^{b}
PP4	$1203.70^{b}{}_{y}$	$1087.17^{b}{}_{y}$	$1207.18^{b}{}_{y}$	$1769.03^{b}{}_{x}$	1316.77^{b}
N means	1279.59_{y}	1207.37_{y}	1366.47_{y}	1980.55_{x}	

CV = 6%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	1226.78	1145.50

F test V
**

4.1.4: Effect of planting patterns and nitrogen level on nodule numbers per bean plant

The nodule counts at all sampling stages gave significant main effects and their interactions in both potato varieties. The Annette variety under low nitrogen of 0 kg/ha and 37.5 kg/ha, had same nodule numbers from sole crop and same hill pattern, these two pattern's nodule numbers were higher than those of alternate row and alternate hill planting. The higher nitrogen levels of 75 kg/ha and 112.5 kg/ha nodule numbers when the three planting patterns of alternate hill, alternate row and same hill were compared but their nodule counts were significantly lower than those of the sole crop. In each of the four planting patterns the lowest nitrogen level of 0 kg/ha had the highest nodule number compared to the other three nitrogen levels of 37.5 kg/ha, 75 kg/ha and 112.5 kg/ha. These three N levels were similar in alternate hill and alternate row patterns but in sole crop and same hill patterns, application of 37.5kg/ha statistically higher number of nodules than 75 and 112.5kg/ha (Table 7a). The second nodule count done at six weeks after emergence generally gave the same results as the first sampling at 0 kg/ha nitrogen level. When the nitrogen level increased to 37.5 kg/ha, same hill nodule numbers were higher than in sole crop which, in turn, had superior nodule count than alternate hill and alternate row intercropping. The higher nitrogen levels of 75 kg/ha and 112.5 kg/ha gave alternate row arrangement as having significantly higher nodule numbers than all the other planting patterns which were in turn not different. There was a decline in nodule numbers with increasing nitrogen levels such that the lowest N level of 0 kg/ha had higher nodule numbers than all the other nitrogen levels in each planting pattern except alternate row. The higher nitrogen levels of 37.5 kg/ha, 75 kg/ha and 112.5 kg/ha realised similar nodule numbers for sole crop and alternate hill. The alternate row arrangement had a different pattern in that the nitrogen levels of 75 kg/ha and 112.5 kg/ha were the same but statistically superior to nitrogen levels of 0 kg/ha and 37.5 kg/ha (Table 8a). The last sampling at eight weeks after emergence showed that under low nitrogen levels of 37.5 kg/ha, the nodule counts for sole crop and same hill planting statistically similar but higher than for alternate row and alternate hills. The higher nitrogen level of 75 kg/ha gave the same hill nodule numbers as being significantly higher than for all the other three planting arrangements. The two patterns of sole crop and alternate row were also not different. Alternate hill planting had the highest nitrogen level of 112.5 kg/ha the planting patterns of sole crop, same hill and alternate hill were the same however the nodule number for these three planting patterns were inferior to those of alternate row planting. There was a trend of decreasing nodule numbers with increase in nitrogen levels except in alternate row and same hill where the numbers increased significantly when the nitrogen levels was increased from 37.5kg/ha to 75 kg/ha (Table 9a).

In B53 potato variety, sampling at 4 weeks after emergence, all the three nitrogen levels of 0 kg/ha, 37.5 kg/ha and 75 kg/ha gave sole crop and same hill nodule numbers as being statistically similar but higher than nodule numbers obtained in both alternate hill and alternate row arrangements, the latter two patterns were also not different. There were no significant differences in nodule count among all the four planting patterns at 112.5kgN/ha. In each of the planting patterns of alternate row and sole crop, there was a decline in nodule numbers as the nitrogen levels were being increased from 0 to 37.5 to 75 kg/ha and from 0 to 37.5kg/ha respectively. The response pattern of sole crop was also followed by same hill pattern while that of alternate row was followed by alternate hill pattern (Table 7b). The sampling at six weeks after emergence, the low nitrogen levels of 0 and 37.5kg/ha, showed nodule counts from sole beans and beans planted with potato in the same hill as not different but significantly higher than the other two planting patterns of alternate hill and alternate row. Higher nitrogen levels to 75kg/ha gave same hill planting nodule numbers as superior to the other three planting patterns of sole crop, alternate row and alternate hills. The highest nitrogen level of 112.5kg/ha had similar nodule counts for alternate row and same hill planting but the two were statistically higher than sole crop and alternate hill patterns. Sole crop nodule numbers were also higher than those of alternate hill planting. There was a significant decrease in nodule numbers when nitrogen levels were increased from 0 to 37.5kg/ha to 75kg/ha in sole crop, 37.5kg/ha to 75kg/ha in alternate hill and from 75 to 112.5kg/ha in same hill planting. In alternate row planting, there was an increase in nodule numbers when nitrogen levels were increased from 0 to 37.5kg/ha and from 75kg/ha to 112.5kg/ha (Table 8b). The last sampling done at eight weeks after emergence that at 0 kg/ha and 75 kg/ha nitrogen level the same hill placement was significantly higher than all the other planting patterns. The other nitrogen levels of 37.5 kg/ha and 112.5 kg/ha there were no significant differences among all the planting patterns. In all the three planting patterns of the sole crop, alternate hill and alternate row there was a decline in nodule numbers as the nitrogen levels increased from 37.5 to 75 kg/ha. Significant decline was noted in same hill planting when nitrogen level was increased from 0 to 37.5kg/ha (Table 9b).

The two varieties turned out to be statistically similar in terms of the nodule numbers obtained when they were intercropped with beans.

Table 7. Effect of planting patterns and nitrogen levels on number of nodules per bean plant when intercropped with (a) (Annette and (b) B53 potato varieties at 4 wks aftter emergence (seasons one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	168.33^{a}_{x}	101.33^{a}_{y}	83.67^{a}_{z}	82.67^{a}_{z}	109.00^{a}
PP2	86.00^{b}_{x}	63.00^{b}_{y}	65.33^{b}_{y}	67.00^{b}_{y}	70.33^{c}
PP3	75.00^{b}_{x}	62.67^{b}_{y}	65.33^{b}_{y}	63.33^{b}_{y}	66.58^{c}
PP4	148.00^{a}_{x}	106.33^{a}_{y}	60.33^{b}_{z}	65.33^{b}_{z}	95.00^{b}
N means	119.93_{x}	83.33_{y}	68.67_{z}	69.58_{z}	

CV = 8%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	165.00^{a}_{x}	103.67^{a}_{y}	99^{a}_{y}	59.67^{a}_{z}	106.84^{a}
PP2	79.67^{b}_{x}	57.33^{b}_{y}	35.33^{b}_{z}	61.00^{a}_{y}	58.33^{b}
PP3	84.33^{b}_{x}	68.33^{b}_{y}	52.00^{b}_{z}	49.67^{a}_{z}	63.58^{b}
PP4	134.00^{a}_{x}	118.67^{a}_{y}	137.33^{a}_{x}	58.67^{a}_{z}	111.66^{a}
N mean	115.75_{x}	87.00_{y}	80.90^{y}	57.25_{z}	

CV = 10%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	85.23	85.10

F test V
ns

Table 8: Effect of planting patterns and nitrogen levels on nodule numbers per plant of beans intercropped with (a) Annette and (b) B53 potato varieties at 6 wks after emergence season one

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	100.67^{ab}	62^{b}_{y}	52.06^{b}_{y}	63.33^{b}_{y}	69.52^{b}
PP2	87.00^{b}_{y}	44.00^{c}_{z}	101.67^{a}_{x}	111.67^{a}_{x}	86.09^{a}
PP3	86.00^{b}_{x}	42.00^{c}_{y}	45.33^{b}_{y}	55.67^{b}_{y}	57.25^{c}
PP4	134.07^{a}_{x}	89^{a}_{y}	52.33^{b}_{z}	50.00^{b}_{z}	81.35^{a}
N means	101.94^{x}	59.25_{z}	62.85_{yz}	70.17_{y}	

CV = 11%

(b)

Planting patterns	Nitrogen levels				
	N1	N2	N3	N4	PP means
PP1	108.33^{a}_{x}	122.33^{a}_{y}	76.00^{b}_{z}	66.33^{b}_{z}	93.25^{b}
PP2	47.67^{c}_{z}	64.33^{b}_{y}	64.33^{b}_{y}	83.67^{a}_{x}	65.00^{c}
PP3	68.33^{b}_{x}	66.33^{b}_{x}	42.33^{c}_{y}	33.00^{c}_{y}	52.50^{c}
PP4	118.33^{a}_{x}	124.67^{a}_{x}	113.00^{a}_{x}	86.00^{a}_{y}	110.50^{a}
N means	85.67_{x}	94.42_{x}	73.92_{x}	67.25_{y}	

CV = 14%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	73.55	80.31

F test V
ns

Table 9: Effect of planting pattern and nitrogen levels on the number of nodules per bean plant intercropped with (a) Annette and (b) B53 potato varieties at 8 wks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	182.00^{a}_{x}	94.00^{a}_{y}	77.00^{b}_{y}	47.33^{b}_{z}	100.08^{a}
PP2	48.00^{c}_{z}	38.00^{b}_{z}	93.00^{b}_{y}	73.67^{a}_{x}	63.17^{b}
PP3	35.00^{c}_{y}	48^{b}_{x}	45.67^{c}_{x}	42.67^{b}_{x}	42.84^{c}
PP4	134.07^{b}_{x}	98^{a}_{y}	143.33^{a}_{x}	51.33^{b}_{z}	106.68^{a}
N means	99.77^{x}	69.50_{y}	89.75_{x}	53.67_{z}	

CV = 10%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	79.67^{b}_{x}	89.33^{a}_{x}	43.00^{b}_{y}	35.67^{a}_{y}	61.92^{ab}
PP2	59.00^{b}_{x}	61.00^{a}_{x}	37.00^{b}_{y}	37.67^{a}_{y}	48.67^{b}
PP3	57.00^{b}_{x}	65.00^{a}_{x}	34.33^{b}_{y}	37.67^{a}_{y}	48.50^{b}
PP4	131.00^{a}_{x}	85.00^{a}_{y}	66.00^{ya}_{z}	54.67^{a}_{z}	84.17^{a}
N means	81.67_{x}	75.08_{x}	45.08_{y}	41.42_{y}	

CV = 11%

Within each column means followed by the same (a,b,c) and x,y,z) within the rows are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V1	V2
	78.19	60.82

F test V
*

4.1.5: Effect of planting patterns and nitrogen levels on nodule wt (g/plant) of bean plants

The beans grown as intercrop with both B53 and Annette potato varieties gave both the main effects and their interactions as being significant at all the sampling intervals. Annette response was such that under low nitrogen 0 kg/ha and 37.5 kg/ha, the nodule weights obtained from sole bean and beans planted in the same hill with potatoes were not different, these two planting patterns were also superior to alternate row and alternate hill patterns at the two nitrogen levels. The latter two patterns were however not significantly different. Increasing the applied nitrogen to 75 kg/ha, gave alternate row weights that were statistically higher than sole crop, alternate hill and same hill nodule weights. The three patterns of sole crop, alternate hill and same hill were also not similar. Using the highest nitrogen level of 112.5 kg/ha, there was no difference between the nodule weights obtained in alternate hill and alternate row patterns as well as between sole crop and same hill patterns. Planting patterns of sole crop gave a significant decline in nodule weights when the nitrogen level was increased from 37.5 to 75 and to 112.5 kg/ha. The decline was significant when nitrogen levels were increased from 37.5 to 75 kg/ha in same hill arrangement. In alternate row pattern only the nitrogen level of 75 kg/ha gave nodule weight higher than all the other three nitrogen levels which were in turn not different. In alternate hill pattern, a significant increase in nodule weight was noted when nitrogen levels were increased from 0 to 37.5kg/ha (Table 10a). The second nodule count done at six weeks after emergence followed the same trend as the first sampling at the low nitrogen rates of 0 and 37.5 kg/ha but when the nitrogen was increased to 75 kg/ha, sole crop nodule weights were significantly higher than all the other planting patterns. Alternate row arrangement came out to be significantly higher than alternate hill and same hill patterns, The two patterns of alternate hill and same hill were in turn not different. The highest nitrogen level of 112.5 kg/ha gave results indicating that sole crop yield and alternate row arrangements were similar but statistically higher than the other two patterns of same hill and alternate, hill which were also not significantly different (Table 11a). The third nodule weight taken at eight weeks after emergence gave nodule counts under low nitrogen of 0 kg/ha responding similarly for all the four planting patterns. The same pattern applied to the nitrogen level of 112.5 kg/ha. When 37.5 kg/ha nitrogen was applied, the sole crop and same hill were similar nodule weight but was significantly higher than the weights obtained from alternate hill and alternate row patterns. At the next nitrogen level of 75 kg/ha, the alternate row arrangement was statistically higher than sole beans, alternate hill and same hill, planting patterns, however these three patterns were also not different. Nitrogen response was such that in sole crop, alternate hill and same hill planting, the nodule weight increased significantly when the nitrogen level was increased from 0 to 37.5kg/ha. Increasing the nitrogen levels from 37.5kg/ha to 75kg/ha resulted in a significant decline in nodule weights, which were maintained even at the highest nitrogen level of 112.5kg/ha (Table 12a).

The bean plants intercropped with B53 potato variety showed almost the same trend as the results obtained from benas intercropped with Annette at the first sampling done at four weeks after emergence except that when 112.5 kg/ha of nitrogen was applied, alternate row yield was higher than the other planting patterns of sole, crop same hill and alternate hill. Sole crop and alternate hill were also not significantly different (Table 10b). At six weeks after emergence the low nitrogen levels of 0 kg/ha and 37.5 kg/ha, the sole crop and same hill patterns were not different, but were statistically higher than alternate row and alternate hill patterns. The higher nitrogen level of 75 kg/ha gave same nodule weights for sole crop and alternate row. These yields were higher than those of alternate hill and same hill planting. The nodule weights of sole crop at 112.5kg/ha nitrogen was higher than the nodules weights of all the other planting patterns. The two patterns of alternate hill and same hill were statistically similar but lower than alternate row nodule weights (Table 11b). Sampling at 8 weeks after emergence followed the same trend as six weeks after emergence except at the highest nitrogen level of 112.5kg/ha where sole crop nodule weight was higher than those nodule weights of all the other three planting patterns, which in turn were similar. There was a significant decline in nodule numbers when nitrogen level was increased from 37.5 to 75kg/ha in sole crop and same hill planting and from 75 to 112.5kg/ha in alternate row planting. The nitrogen levels had no significant effect on the alternate hill planting (Table 12b).

Table 10: Effect of planting patterns and nitrogen levels on nodule wt (g/plant) of beans intercropped with (a) Annette (b) B53 potato varieties, at 4 wks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	0.10^{a}_{x}	0.10^{a}_{x}	0.058^{b}_{y}	0.036^{b}_{z}	0.086^{a}
PP2	0.054^{b}_{y}	0.071^{b}_{y}	0.098^{a}_{x}	0.053^{a}_{y}	0.069^{b}
PP3	0.040^{b}_{z}	0.052^{b}_{y}	0.061^{b}_{x}	0.056^{a}_{x}	0.052^{c}
PP4	0.10^{a}_{x}	0.10^{a}_{x}	0.041^{b}_{y}	0.033^{b}_{y}	0.069^{b}
N mean	0.074_{x}	0.081_{x}	0.065^{c}_{x}	0.045_{y}	

CV = 10%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	0.25^{a}_{x}	0.096^{a}_{y}	0.053^{b}_{yz}	0.036^{b}_{z}	0.110^{a}
PP2	0.085^{b}_{x}	0.035^{b}_{z}	0.088^{a}_{y}	0.045^{a}_{y}	0.047^{c}
PP3	0.031^{c}_{y}	0.034^{b}_{y}	0.047^{b}_{x}	0.035^{b}_{y}	0.037^{d}
PP4	0.23^{a}_{x}	0.085^{a}_{y}	0.035^{c}_{y}	0.019^{c}_{z}	0.077^{b}
N means	0.14_{x}	0.055_{y}	0.042_{z}	0.034_{z}	

CV = 11%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

	V_1	V_2
Variety means	0.069	0.068

F test V
ns

Table 11: Effect of planting patterns and nitrogen levels on nodule wt (g/plant) of beans intercropped with (a) Annette (b) B53 potato varieties, at 6 wks after (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	0.15^{a}_{x}	0.062^{a}_{y}	0.053^{a}_{y}	0.082^{a}_{y}	0.087^{a}
PP2	0.069^{b}_{x}	0.022^{b}_{y}	0.045^{b}_{xy}	0.075^{a}_{x}	0.053^{b}
PP3	0.072^{b}_{x}	0.025^{b}_{z}	0.012^{c}_{z}	0.038^{b}_{y}	0.037^{c}
PP4	0.11^{a}_{x}	0.052^{a}_{y}	0.013^{c}_{z}	0.049^{b}_{y}	0.056^{b}
N mean	0.10_{x}	0.040_{z}	0.031_{z}	0.061_{y}	

CV = 9%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	0.11^{a}_{x}	0.12^{a}_{x}	0.059^{a}_{y}	0.070^{a}_{y}	0.090^{a}
PP2	0.059^{b}_{x}	0.028^{b}_{y}	0.053^{a}_{x}	0.053^{b}_{x}	0.048^{b}
PP3	0.059^{b}_{x}	0.043^{b}_{y}	0.039^{b}_{y}	0.024^{c}_{z}	0.041^{c}
PP4	0.100^{a}_{x}	0.063^{ab}_{y}	0.036^{b}_{z}	0.027^{c}_{z}	0.057^{b}
N mean	0.082_{x}	0.064_{xy}	0.047_{y}	0.044_{y}	

CV = 8%

Within each column means followed by the same superscript (a,b,c) and within each row means followed by the same subscript (x,y,z) not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V1	V2
	0.058	0.059

F test V
ns

Table 12: Effect of planting patterns and nitrogen levels on nodule wt (g/plant) of beans intercropped with (a) Annette (b) B53 potato varieties, at 8 wks after emergence (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	0.032^{a}_{y}	0.051^{a}_{x}	0.016^{b}_{z}	0.011^{a}_{z}	0.028^{a}
PP2	0.029^{a}_{x}	0.031^{b}_{x}	0.026^{a}_{x}	0.013^{a}_{y}	0.025^{ab}
PP3	0.029^{a}_{y}	0.038^{b}_{x}	0.01^{b}_{z}	0.011^{a}_{z}	0.022^{b}
PP4	0.032^{a}_{y}	0.057^{a}_{x}	0.012^{b}_{z}	0.009^{a}_{z}	0.028^{a}
n mean	0.031_{y}	0.044_{x}	0.016z	0.011_{z}	

CV = 10%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	0.071^{a}_{x}	0.089^{a}_{x}	0.056^{a}_{y}	0.046^{a}_{y}	0.066^{a}
PP2	0.055^{b}_{x}	0.047^{b}_{xy}	0.062^{a}_{x}	0.031^{b}_{y}	0.049^{b}
PP3	0.042^{b}_{x}	0.043^{b}_{x}	0.035^{b}_{x}	0.036^{b}_{x}	0.039^{c}
PP4	0.075^{a}_{x}	0.088^{a}_{x}	0.049^{ab}_{y}	0.029^{b}_{y}	0.058^{ab}
N mean	0.061_{x}	0.067_{x}	0.051_{xy}	0.036_{y}	

CV = 13%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V1	V2
	0.026	0.053

F test V
**

4.1.6: Effect of planting patterns and nitrogen levels on bean yield and yield components

4.1.6.1: Bean yield

The bean plants intercropped with both B53 and Annette potato varieties gave significant tmain effects of nitrogen and planting pattern and their interactions. Both potato varieties showed the same trend of yield with the nitrogen and planting pattern treatments Table (13a and b).

At the 0 kg/ha nitrogen level the sole crop yield was higher than all the other three planting patterns. Within the planting patterns, in Annette variety, the alternate row and same hill placements were the same different but inferior to the alternate hill pattern. (Table 13a). B53 had same hill and alternate hill as not being significantly different. The latter two had statistically higher yield than alternate row arrangement (Table 13b). Increasing the nitrogen level to 37.5 kg/ha showed that all the four planting patterns were different, with sole crop realising the highest yield in Annette bean intercrop. B53 gave sole crop and planting in the same hill as being statistically similar and higher than alternate row and alternate hill planting. Increasing nitrogen levels to 75 kg/ha in both potato varieties gave sole crop yield as significantly higher than all the three patterns, although within the intercropped patterns, alternate hill and same hill were similar and higher than alternate row planting patterns. The highest nitrogen levels of 112.5kg/ha gave the sole crop yield to be significantly higher than the yield obtained from the intercropped planting patterns, all of which turned up to be statistically different. In sole crop there was no yield changes when the nitrogen was increased from 0 to 37.5kg/ha for both varieties but a significant increase was noted when the N levels were increased from 37.5 to 75 kg/ha. In alternate hill planting patterns the yield increases were significant when the nitrogen levels were increased from 37.5 to 75 kg/ha and higher N levels of 112.5kg/ha had no response. In same hill pattern, increasing the nitrogen level from 75 kg/ha to 112.5 kg/ha gave a significant decrease in bean yield, intercropped with the two potato varieties (Tables 13a and b).

The two potato varieties showed no significant effect on bean yield.

Table 13: Effect of planting patterns and nitrogen levels on bean yield (kg/ha) intercropped with (a) Annette (b) B53 potato varieties (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	2759.63^{a}_{y}	2723.01^{a}_{y}	3896.72^{a}_{x}	3693.28^{a}_{x}	3268.16^{a}
PP2	854.46^{c}_{y}	651.02^{d}_{y}	760.57^{c}_{y}	1079.81^{d}_{x}	836.47^{c}
PP3	1200.34^{b}_{y}	1471.05^{c}_{y}	1971.84^{b}_{x}	2081.38^{b}_{x}	1681.24^{b}
PP4	839.76^{c}_{z}	1752.77^{b}_{y}	1977.84^{b}_{x}	1580.60^{c}_{y}	1537.74^{b}
N means	1413.55_{z}	1649.46_{y}	2151.27_{x}	2108.77_{x}	

CV = 8%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	2189.63^{a}_{y}	2128.33^{a}_{y}	2754.31^{a}_{x}	2707.36^{a}_{x}	2444.91^{a}
PP2	629.11^{c}_{y}	1408.45^{b}_{x}	1392.81^{c}_{x}	1451.96^{c}_{x}	1220.58^{c}
PP3	1018.63^{b}_{y}	1441.32^{b}_{y}	1974.97^{b}_{x}	1728.33^{b}_{x}	1540.81^{b}
PP4	1052.75^{b}_{y}	2184.67^{a}_{x}	2010.03^{b}_{x}	1223.79^{d}_{y}	1617.81^{b}
N means	1222.53_{z}	1790.69_{y}	2033.03_{x}	1777.86_{y}	

CV = 6%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	1830.90	1708.03

F test	V
	ns

4.1.6.2 Number of pods per bean plant

The beans intercropped with B53 and Annette potato varieties showed a significant response to both the main effects of nitrogen and planting patterns and interactions. (Table 14a and b). Beans intercropped with Annette potato variety indicated that at the low nitrogen levels of 0 and 37.5 kg/ha all the planting patterns were similar. Increasing the nitrogen levels to 75 kg/ha and 112.5 kg/ha gave same pod numbers for sole crop alternate row planting and these pod numbers were superior to alternate hill and same hill patterns which in turn had statistically similar number of pods per plant. Under sole crop and alternate row arrangement, there was no significant effect when nitrogen applied was increased from 0 to and 37.5 kg/ha but when it was increased from 37.5 to 75 kg/ha there was a significant increase in pod numbers. The last two levels of 75 and 112.5kg/ha were not different. Same hill and alternate hill intercropping patterns however showed no response to N application with respect to number of pods/plant (Table 14a).

The beans/B53 intercrop showed no differences among the planting patterns at 0 kgN/ha. The following nitrogen levels of 37.5 kg/ha and 75kg/ha had same pod numbers for sole crop and alternate row planting but significantly higher than those of alternate hill and same hill patterns while at 75 kg/ha, the sole crop and alternate hill pods/plant were also not different. At 112.5 kgN/ha, alternate row patten had statistically higher number of pods/plant than all the other three planting patterns which were, also, not different. There was a significant increase in pod numbers in sole crop when the nitrogen levels were increased from 0 to 37.5 but at 112.5 kg/ha a significant decline was noticed. In alternate row arrangement the number of pods increased significantly when the nitrogen level was increased from 0 to 37.5 kg/ha, with no further changes at higher nitrogen levels. Alternate hill and same hill arrangements showed no response to N. fertilizer application with respect to number of pods/plant.(Table 14b).

The two potato varieties were not significantly different in terms of produced by the bean plants.

Table 14: Effect of planting patterns and nitrogen levels on the number of pods/bean plant intercropped with (a) Annette (b) B53 potato varieties (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	8.67^{a}_{y}	10.67^{a}_{y}	15.00^{a}_{x}	17.33^{a}_{x}	12.90^{a}
PP2	10.33^{a}_{y}	11.00^{a}_{y}	17.33^{a}_{x}	16.00^{a}_{x}	13.67^{a}
PP3	10.00^{a}_{x}	11.00^{a}_{x}	10.33^{b}_{x}	8.67^{b}_{x}	10.00^{b}
PP4	9.67^{a}_{x}	8.67^{a}_{x}	8.33^{b}_{x}	8.33^{b}_{x}	8.75^{b}
n means	9.67_{y}	10.33_{y}	12.75_{x}	12.58_{x}	

CV = 12%

(b)

Planting patterns	Nitrogen levels (KgNha)				
	N1	N2	N3	N4	PP means
PP1	11.67^{a}_{y}	15.67^{a}_{x}	13.33^{ab}_{x}	9.67^{b}_{y}	12.59^{a}
PP2	8.67^{a}_{y}	15.33^{a}_{x}	16.67^{a}_{x}	16.00^{a}_{x}	14.17^{a}
PP3	9.33^{a}_{x}	11.67^{b}_{x}	10.33^{b}_{x}	9.00^{b}_{x}	10.08^{b}
PP4	10.67^{a}_{x}	10.67^{b}_{x}	9.00^{c}_{x}	8.33^{b}_{x}	9.67^{b}
N mean	10.08_{y}	13.33_{x}	12.33_{xy}	10.75_{xy}	

CV = 14%

Within each column means followed by the same superscript (a,b,c) and within each row means followed by the same subscripts (x,y,z)are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	11.33	11.63

F test V
ns

4.1.7: Effect of planting pattern and nitrogen levels on potato yield and yield components

4.1.7.1: Potato tuber yield

The fresh yield analysis gave the main effects of planting patterns and nitrogen levels well as their interaction as being highly significant for both varieties. The Annette variety responded to the treatments by showing that under the low nitrogen level of 0 kg/ha the yields of sole potatoes and potatoes intercropped with beans in the same hill were similar and higher than those of potatoes intercropped with beans in alternate hills and alternate rows. The next three nitrogen levels of 37.5 kg/ha, 75 and 112.5 kg/ha gave similar results except that alternate row intercropping pattern was the same as alternate hill patterns at 37.5kg/ha nitrogen level whereas there was no significant difference between sole crop pattern and alternate row pattern at 112.5kg/ha. The nitrogen response was such that in sole crop, the nitrogen level of 0 kg/ha gave significantly lower yield than the other three nitrogen levels of 37.5 kg/ha, 75 kg/ha and 112.5 kg/ha, whose yields were statistically similar. In alternate row and alternate hill intercrop situations only N application of 112.5kg/ha significantly increased yields. In same hill planting no significant increase was noted with N application (Table 15a).

The other potato variety of B53 showed that within the planting patterns, sole crop yield and same hill pattern yield were not different but were significantly higher than yields obtained from alternate row and alternate hill arrangements at 0 and 37.5kg/ha nitrogen levels. The latter two were also not significantly different. By increasing the nitrogen levels to 75 kg/ha and 112.5 kg/ha the sole crop significantly out yielded the intercrop patterns which in turn were not significantly different. Nitrogen application to sole crop alternate row and alternate hill significantly increased tuber yields but there were no significant changes for the other three nitrogen levels of 37.5 kg/ha, 75 kg/ha and 112.5 kg/ha. Same hill arrangement showed significantly higher yields when 37.5 kgN/ha was applied compared to yields at 0, 75 and 112.5 kgN/ha. (Table 15b).

There were signficant varietal differences with variety annette giving signficantly higher overall yields than variety B53.

Table 15: Effect of planting patterns and nitrogen levels on fresh potato tuber yield (tonnes/ha) of (a) Annette (b) B53 potato varieties (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	24.19^{a}_{y}	25.82^{a}_{x}	25.97^{a}_{x}	26.82^{a}_{x}	25.70^{a}
PP2	21.37^{b}_{y}	22.59^{c}_{y}	22.71^{b}_{y}	27.65^{a}_{x}	23.58^{b}
PP3	20.47^{b}_{y}	21.96^{c}_{y}	20.70^{c}_{y}	24.46^{b}_{x}	21.89^{c}
PP4	24.29^{a}_{x}	24.26^{b}_{x}	24.39^{a}_{x}	24.82^{b}_{x}	23.47^{b}
N mean	22.58_{y}	23.65_{y}	23.44_{y}	25.96_{x}	

CV = 16%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	20.58^{a}_{y}	24.59^{a}_{x}	25.92^{a}_{x}	25.97^{a}_{x}	24.26^{a}
PP2	18.98^{b}_{y}	21.01^{b}_{x}	21.99^{b}_{x}	20.41^{b}_{xy}	20.60^{c}
PP3	17.05^{b}_{y}	22.97^{b}_{x}	22.22^{b}_{x}	21.27^{b}_{x}	20.87^{b}
PP4	21.92^{a}_{yz}	24.85^{a}_{x}	22.04^{b}_{y}	20.09^{b}_{z}	22.23^{c}
N mean	19.63_{y}	23.36_{x}	23.04_{x}	21.93_{x}	

CV = 13%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	23.85	21.87

F test V
**

4.1.7.2: Number of tubers per potato plant

The analysis gave results indicating that both planting patterns and nitrogen treatments had no significant effect on tuber numbers (Tables 16a and b). The varietal difference were significant with Annette variety giving significantly higher tuber numbers per plant than B53.

Table 16: Effect of planting patterns and nitrogen levels on number of pototo tubers per plant (a) Annette (b) B53 potato varieties (season one)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	8.67	9.00	8.33	9.07	8.77
PP2	8.33	8.67	8.33	8.33	8.42
PP3	8.00	8.67	8.00	8.33	8.25
PP4	8.33	8.67	8.67	8.33	8.50
N means	8.33	8.75	8.33	8.52	

Cv = 7%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	6.67	6.67	7.33	7.00	6.92
PP2	6.33	6.67	6.33	6.67	6.50
PP3	6.00	7.00	7.00	6.00	6.50
PP4	6.33	6.33	7.33	6.00	6.50
N means	6.33	6.67	7.00	6.42	

Cv = 9%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	8.49	6.61

F test V
**

4.1.8: Effect of planting pattern and the nitrogen levels on the land equivalent ratios (LER)

The nitrogen and planting pattern interactions were significant when the LER for the two varieties were analysed. In Annette variety the three nitrogen levels of 0, 37.5 and 75kg/ha, planting the two crops (potato and beans) in the same hill had significantly higher LER values than the other two intercrop patterns of alternate hills and alternate row. Increasing the nitrogen levels from 0 to 37.5kg/ha significantly reduced the LER values in alternate row and alternate hill planting. In B53 variety alternate row pattern LER values, significantly increase with N application of 75 kg/ha in alternate row planting. In all the other cases higher nitrogen levels of 75 and 112.5kg/ha reduced the LER values significantly. The two potato varieties had no significant differences in terms of land equivalent ratios (Table 17a and b)

Table 17: Effect of planting pattern and nitrogen levels on land equivalent ratio (LER) in intercropping beans and (a) Annette and (b) B53 potato bean intercrops

(a)

Planting Pattern	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	-	-	-	-	-
PP_2	1.38^{b}_{x}	1.03^{b}_{y}	1.01^{b}_{y}	1.05^{a}_{y}	1.12^{b}
PP_3	1.45^{b}_{x}	1.04^{b}_{y}	1.02^{b}_{y}	1.06^{a}_{y}	1.14^{b}
PP_4	1.67^{a}_{x}	1.41^{a}_{xy}	$1.24^{a}y$	1.20^{a}_{y}	1.38^{a}
N means	1.50_{x}	1.16_{y}	1.09_{y}	1.10_{y}	

CV = 10%

(b)

Planting Pattern	Nitrogen Levels (Kg/N/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	-	-	-	-	
PP_2	1.03^{b}_{y}	1.08^{c}_{y}	1.27^{b}_{x}	1.00^{b}_{y}	1.10^{c}
PP_3	$1.57^{a}x$	1.25^{b}_{y}	1.25^{b}_{y}	1.03^{b}_{z}	1.28^{b}
PP_4	$1.62^{a}x$	$1.56^{a}x$	1.37^{a}_{y}	1.28^{a}_{y}	1.46^{a}
N means	1.41_{x}	1.30_{y}	1.30_{y}	1.10_{z}	

CV = 8%

Within each column means followed with the same superscripts (a,b,c) and within each row means followed by the same subscript (x,y,z) are not significantly different at 5% probability level according to Duncan's Multiple range test.

Variety means	V_1	V_2
	1.21	1.28

F test V
ns

4.2 Season Two (May - August 1984)

4.2.1 General Management

Plant emergence at 4 wks after planting averaged 90% for B53, 94% for Annette and 96% for beans. The missing plants were gapped immediately and since there was enough rain at the beginning of the season, they managed to catch up with the other already established plants.

There was no serious disease or pest problem but spraying using Dimethoate insecticide and Milraz fungicide was done on weekly basis to control any possible out break of pest and fungal diseases respectively. At the end of the growing season there was drought and irrigation was used to alleviate the water problem. Generally, plants did well upto harvesting time.

4.2.2: Effect of planting patterns and nitrogen levels on potato dry matter yield

Only the first sampling at 4 wks after emergence showed significant response. All the other sampling internavals from week 6 to 10 showed a significant response to the main effects of nitrogen and planting patterns as well as their interactions for both B53 and Annette potato varieties (tables 18-21).

In both Annette and B53 varieties at 6 weeks after emergence the low nitrogen level of 0 kg/ha had no significant effect on the planting patterns. When the nitrogen levels were increased to 37.5 kg/ha, 75kg/ha and 112.5 kg/ha sole crop yields came out as higher than the other three planting patterns which were in turn not different, except in B53 variety, where the highest nitrogen level of 112.5 kg/ha gave the sole crop and alternate row arrangements as being similar The other two patterns of alternate hills and same hill were the same. In Annette potato variety, sole crop and alternate row yields showed yield increases when the nitrogen levels were increased from 0 to 37.5 kg/ha and from 37.5 kgN/ha to 75 kgN/ha but no significant change occured when it was increased from 75 to 112.5 kgN/ha. IThe other two planting patterns of alternate hill and same hill yield increases when nitrogen level was increased from 37.5 kg/ha to 75 kg/ha (Table 19a). The B53 potato variety showed significant increases in dry matter yields when the nitrogen levels were raised from 37.5 kg/ha to 75 kg/ha in all the four planting patterns. The overal yields from B53 were higher than yields from Annette (Table 19b).

The third sampling at week 8 after emergence showed both potato varieties at the low nitrogen levels of 0 and 37.5 kg/ha as having same sole crop and same hill dry matter yields that were higher than yields of alternate row and alternte hill. The latter two were also not different. At the higher nitrogen levels of 75 kg/ha and 112.5 kg/ha, Annette variety gave sole crop dry matter yields that were better than for all the other three patterns. The three patterns were also not different. B53 potato variety on the other hand showed the sole crop and same hill planting dry matter yields as not being significantly different. Alternate row and alternate hill dry matter yields were also significantly different at 75 kg/ha nitrogen level. Same hill and alternate hill arrangements were also similar at 112.5 kg/ha nitrogen level but their yields were lower than those obtained from sole crop and alternate row planting, the latter two were also. The Annette variety had a significant increase in sole crop and alternate row yields when the nitrogen levels were increased from 0 to 37.5 kg while in alternate hill pattern positive yield responses were noticed when nitrogen levels were increased from 0 to 37.5 and from 37.5 to 75 kg/ha. In same hill planting applying 37.5kg/ha resulted in yields significantly higher than all the other nitrogen levels. The B53 potato variety had significant increases in yield when nitrogen levels were increased from 37.5 kg/ha to 75 kg/ha in all the four planting arrangements (Table 20a and b).

The last sampling at 10 weeks after emergence both potato varieties' sole crop and same hill planting dry matter yields were not different and had significantly higher dry matter values than alternate row and alternate hill planting at 0 and 37.5 kgN/ha. The latter two patterns were also similar. In Annettee potato variety, increasing the nitrogen level to 75kg/ha had no effect on the planting patterns but when 112.5kg/ha was used, sole crop out yielded the other three planting patterns which were in turn. In B53, increasing the nitrogen level to 75kg/ha gave sole crop, same hill and alternate hill patterns as statistically similar and higher than the alternate row dry matter yields. Application of 112.5kg/ha nitrogen gave sole crop yield as significantly higher than the other three patterns. Alternate row was also higher than the other two statistically similar patterns of same hill and alternate hill. In sole crop Annette, significant increases occured when the nitrogen levels were increased from 37.5kg/ha to 75 and from 75 to 112.5kg/ha. The other planting patterns higher dry matter yields when N level was increased from 37.5 to 75 kgN/ha. In B53 sole crop, alternate hill and same hill planting responded positively to nitrogen applications when nitrogen level was increased from 0 to 37.5kgN/ha (Tables 21a and b).

In the sampling done at eight weeks after emergence the B53 variety had higher dry matter yields than annette variety. In the 10th week sampling no significant varietal differences were detectd.

Table 18: Effect of planting patterns and nitrogen levels on potato dry matter yield (kg/ha) of (a) Annette and (b) B53 varieties 4 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	108.88	117.03	119.10	164.72	132.40
PP2	102.14	105.54	126.67	128.87	120.81
PP3	109.25	109.62	125.17	148.13	123.14
PP4	101.47	118.50	127.77	119.24	121.75
N means	105.54	112.67	129.7	150.16	

C.V = 10%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	106.90	107.02	122.48	160.41	124.31
PP2	109.62	101.47	131.84	152.61	118.94
PP3	102.95	100.62	132.63	167.31	120.93
PP4	109.61	110.72	114.84	153.34	122.41
N means	107.27_y	104.96_y	125.52_y	158.45_x	

CV = 7%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	118.26	110.91

F test V
ns

Table 19: Effect of planting patterns and nitrogen levels on potato dry matter yield (kg/ha) of (a) Annette and (b) B53 varieties 6 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	185.24^{a}_{z}	299.75^{a}_{y}	509.58^{a}_{x}	437.06^{a}_{x}	365.91^{a}
PP2	189.24^{a}_{z}	240.63^{b}_{y}	295.82^{b}_{x}	302.40^{b}_{x}	257.02^{b}
PP3	188.12^{a}_{y}	221.31^{b}_{y}	337.79^{b}_{x}	341.44^{b}_{x}	272.17^{b}
PP4	174.19^{a}_{y}	206.56^{b}_{y}	336.48^{b}_{x}	308.11^{b}_{x}	256.34^{b}
N means	184.20_{z}	242.06_{y}	369.92_{x}	347.25_{x}	

CV = 8%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	272.41^{a}_{y}	293.67^{a}_{y}	455.51^{a}_{x}	474.77^{a}_{x}	374.09^{a}
PP2	243.68^{a}_{y}	205.82^{b}_{y}	386.26^{b}_{x}	462.92^{a}_{x}	297.17^{b}
PP3	268.34^{a}_{y}	204.86^{b}_{y}	326.85^{b}_{x}	305.88^{b}_{x}	276.48^{b}
PP4	286.67^{a}_{y}	203.82^{b}_{y}	366.85^{b}_{x}	332.25^{b}_{x}	301.15^{b}
N means	267.78_{y}	227.04_{y}	371.37_{x}	393.96_{x}	

CV = 14%

Within each column means followed by the same superscripts (a,b,c) and within row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	287.86	312.22

F test V
*

Table 20: Effect of planting patterns and nitrogen levels on potato dry matter yield (kg/ha) of (a) Annette and (b) B53 varieties 8 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels				PP means
	N1	N2	N3	N4	
PP1	420.70^{a}_{z}	520.68^{a}_{y}	545.77^{a}_{y}	607.347^{a}_{x}	523.63^{a}
PP2	281.443^{b}_{z}	379.96^{b}_{y}	445.14^{b}_{x}	480.653^{b}_{x}	396.80^{b}
PP3	251.823^{b}_{z}	339.27^{b}_{y}	437.72^{b}_{x}	461.423^{b}_{x}	372.56^{b}
PP4	403.663^{a}_{y}	489.25^{a}_{x}	391.06^{b}_{y}	411.80^{b}_{y}	411.44^{b}
N means	339.408_{y}	419.79_{x}	454.92_{x}	490.31_{x}	

CV = 9%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				PP means
	N1	N2	N3	N4	
PP1	467.37^{a}_{y}	515.50^{a}_{y}	644.38^{a}_{x}	760.66^{a}_{x}	596.98^{a}
PP2	379.96^{b}_{z}	392.80^{b}_{z}	536.24^{b}_{y}	718.44^{a}_{x}	506.86^{b}
PP3	397.73^{b}_{y}	373.29^{b}_{y}	443.12^{c}_{xy}	500.61^{b}_{x}	428.07^{c}
PP4	432.55^{ab}_{y}	474.76^{a}_{y}	604.38^{a}_{x}	532.54^{b}_{xy}	511.06^{b}
N Means	419.40_{y}	430.09_{y}	557.03_{x}	628.06_{x}	

CV = 14%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	426.11	510.74

F test V
•

Table 21: Effect of planting patterns and nitrogen levels on potato dry matter yield (kg/ha) of (a) Annette and (b) B53 varieties 10 wks after emergence (season two)

(a)

Planting	Nitrogen levels (KgN/ha)				
patterns	N1	N2	N3	N4	PP means
PP1	556.24^{a}_{z}	586.61^{a}_{z}	710.30^{a}_{y}	985.10^{a}_{x}	709.56^{a}
PP2	445.88^{b}_{y}	449.51^{b}_{y}	720.33^{a}_{x}	774.75^{b}_{x}	597.62^{ab}
PP3	424.40^{b}_{y}	465.13^{b}_{y}	664.38^{a}_{x}	724.37^{b}_{x}	569.57^{b}
PP4	553.28^{a}_{y}	577.72^{a}_{y}	718.67^{a}_{x}	747.33^{b}_{x}	649.25^{ab}
N means	494.95_{y}	519.75_{y}	703.42_{x}	807.89_{x}	

CV = 11%

(b)

Planting	Nitrogen levels (KgN/ha)				
patterns	N1	N2	N3	N4	PP means
PP1	492.54^{a}_{z}	689.56^{ab}_{y}	853.98^{a}_{xy}	1006.56^{a}_{x}	760.67^{a}
PP2	396.98^{b}_{z}	591.79^{b}_{y}	686.60^{b}_{y}	813.99^{b}_{x}	622.39^{b}
PP3	402.17^{b}_{y}	586.61^{b}_{y}	782.88^{a}_{x}	708.07^{c}_{x}	619.94^{b}
PP4	557.72^{a}_{y}	728.81^{a}_{x}	766.08^{a}_{x}	688.82^{c}_{y}	685.36^{ab}
N mean	462.36_{z}	649.20_{y}	772.39_{x}	804.37_{x}	

CV = 10%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	631.50	672.09

F test V

ns

4.2.3: Effect of planting patterns and nitrogen levels on bean dry matter yield

The First sampling at 4 weeks after emergence showed no significant responses. Sampling done latter at 6, 8 and 10 weeks after emergence indicated the main effects of nitrogen and planting patterns as well as as the interactions as significant (Tables 22-25)..

In the week 6 the Annette/bean intercrop, the lowest nitrogen level of 0 kg/ha the sole crop bean dry matter yield was higher than the other three planting patterns, which were not different. The other nitrogen levels of 37.5 kg/ha and 112.5 kg/ha gave sole crop yield and alternate row yields as similar. The three patterns of alternate row, alternate hill and same hill were also not significantly different at 112.5kg/ha nitrogen. At the 75kg/ha nitrogen level alternate row dry matter yield was lower than the yield of the other three planting patterns of sole crop, same hill and alternate hill planting the three were statistically similar. In all the three planting patterns of sole crop, alternate row and same hill, the nitrogen effect was significant only when the nitrogen level was increased from 0 to 37.5 kg/ha. Further increments from 37.5 to 75 to 112.5 kg/ha had no significant effect on the yield obtained. Alternate hill planting gave a significant yield increase when nitrogen level was increased from 37.5 to 75kgN/ha (Table 23a).

Intercropping beans with B53 showed that at 0 kgN/ha sole crop significantly out yield the three patterns which in turn were not different. At 37.5kg/ha nitrogen only alternate row dry matter were yields lower than the other three patterns of sole crop, same hill and alternate hill planting, which were similar. Application of

75kgN/ha had no effect on the patterns. Increasing the nitrogen level to 112.5 kg/ha gave sole crop and alternate row planting as being similar and higher than both alternate hill and same hill planting. The latter two were also the same. A significant yield increase was noted when the nitrogen level was increased from 75 to 112.5 kg/ha in sole crop. Nitrogen levels being increased from 0 to 37.5 to 75 kg/ha has no significant effect on sole crop and alternate row while in alternate hill and same hill, all the four levels has no significant effect on yield. The two varieties responded similarly (Table 23b)

In the 8th week sampling, the first nitrogen level of 0kg/ha showed sole crop beans and beans planted in alternate rows as responding similarly to treatments and were also superior to same hill and alternate hill planting patterns. The three higher levels of 37.5kg/ha, 75 kg/ha and 112.5 kg/ha gave only sole crop yields as being higher than the other planting patterns of alternate row, alternate hill and same hill. The three patterns were the same at 75kg/ha. The sole crop, and same hill planting patterns increased in dry matter yield when the nitrogen levels were increased from 75 kg/ha to 112.5 kg/ha, ehile the other patterns of alternate hill had a yield increase when the nitrogen level was increased from 37.5 kg/ha to 75 kg/ha. Alternate row yields remained similar even when the nitrogen levels were increased from 0 to 37.5 to 112.5kg/ha. Sampling done at the same time for beans intercropped with B53 showed similar results except at the low nitrogen level of 0 kg/ha where sole crop yield was higher than yield from the other planting patterns. Within the planting patterns, alternate row and alternate hill yields were similar, but lower than same hill planting yields. The nitrogen effect on the planting patterns was such that in sole crop, alternate hill and same hill patterns, a significant increase occured when the nitrogen level was increased 75 kg/ha to 112.5kg/ha. In alternate row planting, a significant increase was noted when the nitrogen level was increased from 0 to 37.5kg/ha. The variety differences indicated that beans intercropped with B53 potato variety gave significantly higher yields than when intercropped with Annette potato variety. (Table 24 a and b).

The last sampling done at 10 wks after emergence gave an indication that for both bean /Annette and bean /B53 intercrop, sole crop significantly out yielded all the other three planting patterns over the four nitrogen levels. The three patterns were in turn not different at each nitrogen level for both varieties except alternate hill and same hill dry matter yields which were statistically similar and higher than alternate row planting dry matter yields at 0kgN/ha in Annette variety. Nitrogen response in Annette was such that for sole crop the two nitrogen levels of 0 and 37.5kg/ha were similar and lower than yields obtained at 75 and 112.5kg/ha. Significant increases in dry matter yield also occured when nitrogen levels were increased from 0 to 37.5kg/ha and from 75 to 112.5kg/ha in alternate row and alternate hill planting respectively. In alternate row and same hill planting yields obtained at 37.5kg/ha and 75kg/ha were not significantly different and so were yields obtained at 75 and 112.5kg/ha (Table 25a). Intercropping beans with B53 potato variety gave significant yield increases when nitrogen levels were increased from 0 to 37.5kg/ha and from 75 to 112.5kg/ha in sole crop, alternate row and same hill planting patterns. In alternate hill planting a significant increase was noted only when nitrogen was increased from 0 to 37.5kg/ha. Any further increases in nitrogen gave no significant yield changes (Table 25b).

The variety differences at 10 weeks after emergence were not significant.

Table 22: Effect of planting patterns and nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 4 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	362.40	388.80	400.60	434.16	396.49
PP2	354.73	402.23	392.60	402.06	385.96
PP3	367.40	378.53	311.16	388.06	361.29
PP4	344.80	303.83	348.53	305.20	325.60
N means	357.33	368.35	363.22	384.40	

CV = 5%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	379.26	400.60	485.90	440.33	426.52
PP2	376.30	400.00	486.63	421.66	421.02
PP3	399.93	409.03	484.53	382.93	419.11
PP4	375.56	416.33	468.13	385.16	395.42
N means	382.76	406.30	481.49	407.52	

CV = 4%

Within each column means followed by the same superscripts (a,b,c) and with each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	367.34	415.52

F test V

ns

Table 23: Effect of planting patterns and nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 6 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	545.90^{a}_{y}	682.41^{a}_{x}	632.26^{a}_{x}	672.25^{a}_{x}	633.21^{a}
PP2	425.91^{b}_{y}	638.18^{a}_{x}	534.20^{b}_{x}	596.26^{ab}_{x}	548.64^{b}
PP3	425.32^{b}_{y}	507.75^{b}_{y}	612.04^{a}_{x}	561.01^{b}_{xy}	526.53^{b}
PP4	419.61^{b}_{y}	558.71^{b}_{x}	607.45^{a}_{x}	561.82^{b}_{x}	536.90^{b}
N means	454.19_{y}	596.76_{x}	596.48_{x}	597.63_{x}	

CV = 9%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	578.12^{a}_{y}	598.48^{a}_{xy}	506.63^{a}_{y}	681.44^{a}_{x}	591.17^{a}
PP2	520.79^{b}_{y}	481.98^{b}_{y}	574.80^{a}_{xy}	668.48^{a}_{x}	561.51^{b}
PP3	540.19^{b}_{x}	554.93^{a}_{x}	558.27^{a}_{x}	586.64^{b}_{x}	577.50^{ab}
PP4	510.27^{b}_{x}	531.16^{a}_{x}	579.46^{a}_{x}	569.60^{b}_{x}	523.62^{b}
N means	537.34_{y}	541.64_{y}	554.79_{y}	626.541_{x}	

CV = 10%

Within each column means followed by the same superscripts (a,b,c,) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	561.32	563.46

F test V
ns

Table 24: Effect of planting patterns and nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 8 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	683.66^{a}_{z}	754.77^{a}_{yz}	797.72^{a}_{y}	979.19^{a}_{x}	803.84^{a}
PP2	616.26^{a}_{y}	641.44^{b}_{xy}	662.29^{b}_{xy}	732.53^{b}_{x}	663.13^{b}
PP3	494.05^{b}_{yz}	517.00^{c}_{y}	629.59^{b}_{x}	410.31^{c}_{z}	512.74^{c}
PP4	497.76^{b}_{z}	513.31^{c}_{z}	683.65^{b}_{y}	804.55^{b}_{x}	624.82^{b}
N means	572.93_{y}	606.63_{y}	693.31_{y}	731.65_{x}	

CV = 13%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	694.77^{a}_{y}	739.21^{a}_{y}	925.87^{a}_{y}	1079.93^{a}_{x}	859.95^{a}
PP2	538.49^{c}_{y}	753.28^{a}_{x}	700.70^{b}_{xy}	818.39^{b}_{x}	703.72^{b}
PP3	565.90^{c}_{y}	607.37^{b}_{y}	667.22^{b}_{y}	1031.05^{a}_{x}	717.88^{b}
PP4	617.74^{b}_{y}	624.41^{b}_{y}	674.04^{b}_{y}	916.24^{b}_{x}	708.11^{b}
N means	604.23_{z}	681.07_{yz}	741.96_{y}	966.41_{x}*	

CV = 14%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	651.13	747.42
F = test	V	
	**	

Table 25: Effect of planting patterns and nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 10 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha0				
	N1	N2	N3	N4	PP means
PP1	647.34^{a}_{y}	655.49^{a}_{y}	829.54^{a}_{x}	844.36^{a}_{x}	744.18^{a}
PP2	368.85^{c}_{z}	470.32^{b}_{y}	568.10^{b}_{xy}	600.39^{b}_{x}	501.92^{b}
PP3	534.76^{b}_{y}	559.20^{b}_{y}	591.06^{b}_{y}	705.85^{b}_{x}	597.72^{b}
PP4	485.87^{b}_{y}	559.95^{b}_{y}	621.27^{b}_{xy}	662.90^{b}_{x}	582.50^{b}
N means	509.20_{y}	561.24_{y}	652.49_{y}	703.37_{x}	

CV = 11%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	576.24^{a}_{z}	779.18^{a}_{y}	771.04^{a}_{y}	919.16^{a}_{x}	761.41^{a}
PP2	406.63^{b}_{z}	546.61^{b}_{y}	531.05^{b}_{y}	693.26^{b}_{x}	544.39^{b}
PP3	442.17^{b}_{z}	550.317^{b}_{x}	550.98^{b}_{x}	619.16^{b}_{x}	540.66^{b}
PP4	407.36^{b}_{z}	542.92^{b}_{y}	501.43^{b}_{y}	669.56^{b}_{x}	530.32^{b}
N means	458.10_{z}	604.61_{y}	588.63_{y}	725.29_{x}	

CV = 13%

Within each column means followed by the same superscripts (a,b,c) and within row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	606.58	594.20

F test V
ns

4.2.4: Effect of planting patterns and nitrogen levels on the number of nodules per bean plant

The first sampling at 4 wks after emergence gave the nitrogen and planting pattern together with their interactions as being significant when the beans were intercropped with both Annette and B53 potato varieties (Table 26 a and b).

When the beans were intercropped with Annette potato variety the planting pattern response was such that under low nitrogen level of 0 kg/ha the nodule numbers from sole crop were similar to the numbers obtained from same hill planting, these two patterns nodule counts were higher than those of alternate hill and alternate row planting patterns. Higher the nitrogen levels to 37.5 kg/ha gave sole crop and alternate row nodule counts as not being similar and higher than the nodule numbers obtained from alternate hill and same hill planting patterns the latter two were also not different. The nitrogen level of 75 kg/ha gave only sole crop counts as being higher than the counts of the other three planting patterns. Within the three patterns, alternate row and same hill were statistically similar and significantly higher than alternate hills. The highest nitrogen level of 112.5 kg/ha had no significant effect on the planting patterns. Sole crop yields showed a significant decline in nodule numbers when the nitrogen levels were increased from 37.5 kg/ha to 75 kg/ha but increasing the level from 0 kg/ha to 37.5 kg/ha and from 75 kg/ha to 112.5 kg/ha showed no effects on nodule numbers. In alternate row, a increase in nodule numbers was observed when the nitrogen level was increased from 0 to 37.5kg/ha and a decrease observed when the nitrogen was increased from 37.5 to 75kg/ha. Same hill placement showed a significant decrease when nitrogen was increased from 0 to 37.5kg/ha . Alternate hill planting showed a significant yield decrease when the nitrogen level was increased from 37.5 to 75kgN/ha (Table 26a).

In the case of B53 potato variety intercropped with beans, the planting pattern showed a trend in nodule numbers similar to that of Annette variety at 0 kg/ha nitrogen, but when the nitrogen level was increased to 37.5 and 75kg/ha, the sole crop out yielded the other planting patterns which were also not different. Like Annette variety, the highest nitrogen level of 112.5 kg/ha had no significant effect on the planting patterns. In all the four planting patterns, there was a decline in nodule numbers when nitrogen level was increased from 0 to 37.5. Other increases in nitrogen level had no effect except in alternate hill and alternate row where an increase occured when nitrogen was increased from 75 to 112.5 kg/ha. (Table 26b).

The second nodule count done at six weeks after emergence also indicated the main effects of nitrogen and planting pattern as well as their interactions as being significant when intercropped with both B53 and Annette varieties potato. The intercrop with Annette potato variety gave an indication that under low nitrogen levels of 0 kg/ha and 37.5 kg/ha, there were no differences in the nodule count between sole beans and beans planted in the same hill with potato plants. The nodule counts of the two were also higher than those obtained by planting on alternate rows and alternate hills. At the highest nitrogen levels of 112.5 kg/ha sole crop nodule numbers were higher than for the other three planting patterns. At 75kg/ha sole crop and alternate row nodule numbers were similar but higher than the nodule numbers of the other two patterns of alternate hill and same hill. The latter two were also similar. The response to nitrogen was such that significant increases in nodule number were noted when the nitrogen levels were increased from 37.5kg/ha to 75kg/ha and from 75 to 112kg/ha in alternate row and alternate hill respectively. Significant decline was noted when the nitrogen levels were increased from 75 to 112.5kg/ha and from 37.5 to 75kg/ha in sole crop and same hill patterns respectively (Table 27a). Intercropping beans with B53 potato variety gave sole crop and same hill placements as not significantly different at 0 kg/ha nitrogen. Nodule counts of the two patterns were however higher than of the other two planting patterns. Increasing nitrogen levels to 37.5 kg/ha gave sole crop yields as being higher than the yields of the other three planting patterns which were in turn not different. The nitrogen level of 75kg/ha gave sole crop alternate hill and alternate row as being similar and higher than same hill planting. The last nitrogen level of 112.5kg/ha gave sole crop and alternate row as being and significantly higher than the other two patterns of alternate hill and same hill. Significant decline in nodule count was noted when the nitrogen level was increased from 0 to 37.5kg/ha in both sole crop and same hill planting (Table 27b).

Counting done at week 8 and 10 showed no significant nitrogen and planting pattern effects (Tables 28 a, b and 29 a and b).

Table 26: Effect of planting patterns and nitrogen levels on the number of nodules per bean intercropped with (a) Annette and (b) B53 potato varieties 4 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	174.33^{a}_{x}	160.33^{a}_{x}	138.31^{a}_{y}	130.67^{a}_{y}	150.92^{a}
PP2	136.67^{b}_{y}	151.33^{a}_{x}	128.67^{b}_{y}	133.67^{a}_{y}	137.59^{b}
PP3	131.81^{b}_{x}	137.41^{b}_{x}	102.00^{c}_{y}	132.00^{a}_{x}	125.81^{b}
PP4	169.00^{a}_{x}	138.00^{b}_{y}	125.67^{b}_{y}	127.67^{a}_{y}	140.09^{ab}
N means	152.92_{x}	146.75_{x}	123.66_{y}	131.00_{y}	

CV = 6%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	178.33^{a}_{x}	150.33^{a}_{y}	148.33^{a}_{y}	140.67^{a}_{y}	159.42^{a}
PP2	156.67^{b}_{x}	134.33^{b}_{y}	128.67^{b}_{y}	145.67^{a}_{x}	146.34^{b}
PP3	149.81^{b}_{x}	135.33^{b}_{y}	129.00^{b}_{y}	146.00^{a}_{x}	140.04^{b}
PP4	169.00^{a}_{x}	138.00^{b}_{y}	123.67^{b}_{y}	137.67^{a}_{y}	141.92^{b}
N means	163.45_{x}	139.50_{y}	132.42_{y}	142.50_{y}	

CV = 8%

Within each column, means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	138.03	146.93

F test V
ns

Table 27: Effect of planting patterns and nitrogen levels on the number of nodules per bean intercropped with (a) Annette and (b) B53 potato varieties 6 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	152.33^{a}_{x}	148.34^{a}_{xy}	159.04^{a}_{x}	145.91^{a}_{y}	151.41^{a}
PP2	128.36^{b}_{y}	121.46^{b}_{y}	158.36^{a}_{x}	127.94^{b}_{y}	134.00^{b}
PP3	121.91^{b}_{xy}	124.33^{b}_{xy}	101.36^{b}_{y}	132.00^{b}_{x}	119.90^{c}
PP4	145.00^{a}_{x}	142.39^{a}_{x}	108.00^{b}_{y}	127.33^{b}_{y}	130.68^{b}
N means	136.90_{x}	134.13_{x}	131.69_{x}	133.30_{x}	

CV = 8%

(b)

Planting patterns	Nitrogen levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	158.33^{a}_{x}	147.00^{a}_{y}	140.31^{a}_{y}	140.33^{a}_{y}	146.49^{a}
PP2	128.33^{b}_{y}	132.09^{b}_{xy}	135.46^{a}_{xy}	140.00^{a}_{x}	133.97^{b}
PP3	133.00^{b}_{xy}	135.41^{b}_{x}	132.97^{a}_{xy}	124.91^{b}_{y}	131.57^{b}
PP4	159.21^{a}_{x}	137.39^{b}_{y}	125.33^{b}_{y}	123.67^{b}_{y}	136.30^{b}
N mean	144.71_{x}	137.97_{xy}	133.52_{y}	132.23_{y}	

CV = 8%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	134.00	137.08

F test V
ns

Table 28: Effect of planting patterns and nitrogen levels on the number of nodules per bean intercropped with (a) Annette and (b) B53 potato varieties 8 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP Means
PP1	38.92	41.29	34.00	37.67	37.97
PP2	28.39	36.00	33.00	37.06	33.86
PP3	23.67	30.93	29.33	34.39	29.58
PP4	37.94	43.33	37.00	29.00	36.82
N means	32.23	37.89	33.33	34.53	

CV = 18%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	41.67	38.94	36.00	34.00	37.65
PP2	31.98	32.94	32.31	36.94	33.54
PP3	32.00	33.93	28.46	34.69	32.27
PP4	37.00	32.31	33.00	25.00	31.83
N Means	35.66	34.53	32.44	32.66	

CV = 15%

Within each column means followed by the same superscripts (a,b,a) and within each row followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	34.56	33.82

F test V
ns

Table 29: Effect of planting patterns and nitrogen levels on the number of nodules per bean intercropped with (a) Annette and (b) B53 potato varieties 10 wks after emergence (season two)

(a)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	28.50	31.67	26.33	32.94	29.86
PP2	29.58	30.33	26.67	25.33	27.98
PP3	28.42	30.00	25.67	28.34	28.11
PP4	27.67	30.00	30.69	26.39	28.69
N means	28.55	30.50	27.34	28.25	

CV = 11%

(b)

Planting patterns	Nitrogen levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	30.67	31.00	23.36	24.00	27.26
PP2	26.39	23.33	23.00	20.36	23.27
PP3	23.94	20.34	26.94	25.94	24.29
PP4	26.34	26.00	27.00	21.36	25.18
N means	26.84	25.17	25.08	22.92	

CV = 14%

Within each column means followed by the same superscrips (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	28.66	25.00

F test V
ns

4.2.5. Effect of planting patterns and nitrogen levels on nodule weight (g/plant) of beans plants

The first nodule weighing done at 4 weeks after emergence, beans intercropped with both Annette and B53 potato varieties gave the main affects of planting patterns and nitrogen as well as their interactions as being significant. In beans intercropped with Annette potato variety, the nodule weight for sole crop and same hill planting were not different at 0 and 37.5kg/ha but were higher than the nodule weight from alternate row and alternate hill planting patterns. Increasing the nitrogen levels to 75kg/ha gave sole crop yields and alternate row yields as not being similar and higher than those of same hill and alternate hill arrangements, which were also not significantly different. At the highest nitrogen level of 112.5kg/ha there were no significant differences in the planting patterns. In sole crop planting and alternate hill patterns, the first two nitrogen levels of 0 and 37.5kg/ha had significantly higher nodule weights than the next two levels of 75kg/ha and 112.5kg/ha. In alternate rows arrangement the nodule numbers at 0kg/ha nitrogen and 75/ha nitrogen were not different, the same applied to the nitrogen levels of 37.5, 75 and 112.5kg/ha. Significant decline in nodule occured in same hill planting when nitrogen was increased from 37.5 to 75kg/ha. (Table 30a). Beans intercropped with B53 showed that at the lowest nitrogen level of 0kg/ha, the nodule weights obtained from the four planting patterns were similar. At 37.5kg/ha nitrogen sole crop and alternate hill out-yielded the other planting patterns. At 75 and 112.5kg/ha alternate row out-yielded the other three patterns of sole crop, alternate hill and same hill planting. In sole crop and alternate hill planting, in nodule weight was noted when the nitrogen level was increased from 0 to 37.5 and from 37.5 to 112.5kg/ha. Alternate row and same hill planting showed a significant decline in nodule weight only when the nitrogen level was increased from 0 to 37.5kg/ha (Table 30b).

The sampling at 6 weeks after emergence also showed that bean intercrop with both potato varieties gave the main effects and their interactions as being significant. The results indicated that intercropping beans with Annette potato variety, sole crop and same hill nodule gave weights as being statistically similar and higher than those of the other two patterns of alternate row and alternate hill. The latter two were also not different. At 37.5kg/ha same hill and sole crop planting significantly out-weighed the other planting patterns which were in turn. Alternate row was significantly higher than the other planting patterns at 75 and 112.5kg/ha. The significant decreases in nodule weight were noted when the nitrogen levels were increased from 75 to 112.5kg/ha in all the four planting patterns. Another significant decrease occured when nitrogen levels were increased from 0 to 37.5 KgN/ha in same hill planting (Table 31a). Beans intercropped with B53 showed that at 0 kgN/ha all the patterns were similar. Increasing the nitrogen level to 37.5N/ha gave sole crop alternate row and alternate hill as well as sole crop alternate row and same hill as being the same. Alternate hill and same hill were also different. At 75 and 112.5kgN/ha alternate hill significantly out-yielded all the other planting patterns with same hill being significantly the lowest at 112.5kgN/ha. The nitrogen effect on planting patterns was such that for the three planting patterns of sole crop, same hill and alternate hill, the first two nitrogen levels of 0kg/ha and 37.5kg/ha nodule weights were higher than the other two levels of

75 and 112.5kg/ha. Alternate row planting gave yields at 0, 37.5 and 75kg/ha as well as yields at 75 and 112.5kgN/ha as being statistically similar (Table 31b).

The sampling done at eight and ten weeks gave only the main effect of nitrogen as being significant for both varieties. On the 8th week, bean intercrop with Annette gave the first nitrogen levels of 0 and 37.5kg/ha as not being significantly different but 37.5kgN/ha was higher than the nodule weight at the other two levels of 75 and 112.5kgN/ha. Weights obtained at 0, 75kg/ha and 112.5kg/ha were also not different (Table 32a). The nitrogen response in B53 bean intercrop was such that the level of 37.5kg/ha was higher than 0kg/ha, 75kg/ha and 112.5kg/ha. The three N levels of 37.5 and 112.5kgN/ha were not different, while 0, 75 and 112.5kgN/ha were also similar (Table 32b). On the 10th week the beans intercropped with Annette potato variety gave the nodule weight from 0kg/ha, 37.5kg/ha and 75kg/ha as not being different. 0, 75 and 112.5kg/ha were also statistically similar (Table 33a). The intercrop with B53 gave similar nodule weights for 0 and 37.5kg/ha and the weights were statistically higher than nodule weights from 75 and 112.5kg/ha. The latter two were also not significantly different. (tables 33b). There were no significant varietal differences at all sampling intervals.

Table 30: Effect of planting patterns and nitrogen levels on nodule weight (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties at 4 weeks after emergence (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	0.049^{a}_{x}	0.041^{a}_{x}	0.027^{a}_{y}	0.023^{a}_{y}	0.035^{a}
PP2	0.036^{b}_{x}	0.028^{b}_{y}	0.031^{a}_{xy}	0.024^{a}_{y}	0.030^{a}
PP3	0.035^{b}_{x}	0.030^{b}_{x}	0.020^{b}_{y}	0.026^{a}_{y}	0.028^{a}
PP4	0.049^{a}_{x}	0.040^{a}_{y}	0.019^{b}_{z}	0.026^{a}_{z}	0.034^{a}
N means	0.042_{x}	0.035_{x}	0.025_{y}	0.025_{y}	

CV = 10%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N1	N2	N3	N4	PP means
PP1	0.040^{a}_{x}	0.034^{a}_{y}	0.016^{b}_{z}	0.019^{b}_{z}	0.027^{b}
PP2	0.046^{a}_{x}	0.028^{ab}_{y}	0.027^{a}_{y}	0.032^{a}_{y}	0.033^{a}
PP3	0.044^{a}_{x}	0.025^{b}_{y}	0.019^{b}_{z}	0.014^{b}_{z}	0.026^{b}
PP4	0.038^{a}_{x}	0.021^{b}_{y}	0.017^{b}_{y}	0.016^{b}_{y}	0.023^{b}
N means	0.042_{x}	0.027_{y}	0.020_{y}	0.020_{y}	

CV = 10%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V1	V2
	0.031	0.027

F test V
ns

Table 31: Effect of planting patterns and nitrogen levels on nodule weight (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties at 6 weeks after emergence (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.043^{a}_{x}	0.030^{a}_{xy}	0.018^{b}_{y}	0.005^{b}_{z}	0.024^{a}
PP_2	0.016^{b}_{y}	0.019^{b}_{y}	0.028^{a}_{x}	0.010^{a}_{y}	0.018^{a}
PP_3	0.018^{b}_{x}	0.014^{b}_{x}	0.014^{b}_{x}	$0.0052b_{y}$	0.013^{a}
PP_4	0.043^{a}_{x}	0.025^{a}_{y}	0.012^{b}_{y}	0.003^{b}_{z}	0.018^{a}
N means	0.030_{x}	0.022_{x}	0.018_{x}	0.0058_{y}	

CV = 14%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.022^{a}_{x}	0.020^{ab}_{x}	0.007^{b}_{y}	0.0044^{b}_{y}	0.013^{ab}
PP_2	0.027^{a}_{x}	0.019^{ab}_{x}	$0.016^{a}y$	0.010^{a}_{y}	0.018^{a}
PP_3	0.023^{a}_{x}	0.024^{a}_{x}	0.0052^{b}_{y}	0.0037^{b}_{y}	0.014^{ab}
PP_4	0.019^{a}_{x}	0.015^{ab}_{x}	0.0030^{b}_{y}	0.0029^{c}_{y}	0.010^{b}
N means	0.023_{x}	0.020_{x}	0.0078_{y}	0.0053_{y}	

CV = 16%

Within each column means followed by the same superscripts and within each row, means followed by the same superscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	0.018	0.014

F test V
ns

Table 32: Effect of planting patterns and nitrogen levels on nodule weight (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties at 8 weeks after emergence (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.0034	0.0034	0.0027	0.0027	0.0031^a
PP_2	0.0033	0.0037	0.0032	0.0024	0.0031^a
PP_3	0.0031	0.0034	0.0028	0.0031	0.0031^a
PP_4	0.0032	0.0037	0.0024	0.0028	0.0030^a
N means	0.0032_{xy}	0.0036_x	0.0028_y	0.0028_y	

CV = 15%

(b)

Planting Pattern	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.0032	0.0042	0.0031	0.0034	0.0035^a
PP_2	0.0032	0.0044	0.0037	0.0044	0.0039^a
PP_3	0.0029	0.0040	0.0039	0.0036	0.00376^a
PP_4	0.0037	0.0050	0.0041	0.0031	0.0042^a
N means	0.0030_y	0.0044_y	0.0037_{yx}	0.0036_{yx}	

CV = 16%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	0.0031	0.0038

F test V
ns

Table 33: Effect of planting patterns and nitrogen levels on nodule weight (g/plant) of Beans Intercropped with (a) Annette and (b) B53 potato varieties at 10 weeks after emergence (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.0029	0.0036	0.0021	0.0021	0.0027^a
PP_2	0.0022	0.0034	0.0029	0.0024	0.0027^a
PP_3	0.0024	0.0026	0.0029	0.0023	0.0025^a
PP_4	0.0027	0.0036	0.0031	0.0020	0.0028^a
N means	0.0026_{xy}	0.0033_x	0.0028_{xy}	0.0022_y	

CV = 18%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	0.0029	0.0039	0.0021	0.0014	0.0026^a
PP_2	0.0031	0.0041	0.0024	0.0020	0.0029^a
PP_3	0.0034	0.0030	0.0019	0.0016	0.0025^a
PP_4	0.0031	0.0034	0.0018	0.0019	0.0026^a
N means	0.0031_x	0.0036_x	0.0021_y	0.0017_y	

CV = 17%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	0.0027	0.0027

F test	V
	ns

4.2.6 Effect of planting patterns and nitrogen levels on bean yield and yield components

4.2.6.1: Bean Yield:

Both the Annette/bean and B53/bean intercrips responded similarly to treatments by showing significant main effects and interactions. Annette/bean intercrop yielded the same for sole crop and alternate row planting at 0kg/ha nitrogen. The yields of the two patterns were higher than those obtained from alternate hill and same hill planting. When the nitrogen levels were increased to 37.5kg/ha and above, sole crop significantly out yielded all the other planting patterns. Within the patterns, alternate row and same hill were similar and superior to alternate hill planting at 37.5kg/ha. At 75kg/ha and 112.5kg/ha the three patterns of alternate row, alternate hill and same hill were different with alternate row having the lowest yields at both nitrogen levels. Bean yields increased when the nitrogen levels were increased to above 37.5kg/ha in sole croping and alternate hill planting. Same hill planting yields increased significantly when the nitrogen levels were increased from 0 to 37.5 and from 37.5 to 75kgN/ha. A yield decrease occured when nitrogen level was increased from 37.5 to 75kg/ha in alternate row planting (Table 34a). The intercrop done with B53 potato variety gave sole crop yield to be significantly higher than all the other planting patterns over all the nitrogen levels. The three patterns of alternate row, alternate hill and same hill were not different at 37.5 and 75kg/ha nitrogen levels. At 0kg/ha nitrogen level, alternate hill and same hill patterns were similar alternate row planting pattern. In sole crop, alternate row and alternate hill, significant yield increase was noted when the nitrogen level was increased from 75 to 112.5kg/ha. Same hill planting showed a significant yield decrease when nitrogen level was increased from 0 to 37.5kg/ha. The two potato varieties not significantly different with respect to bean yields obtained (Table 34b).

Table 34: Effect of planting patterns and nitrogen levels on bean yield (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties (Season two)

(a)

Planting Pattern	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	2073.33^{a}_{z}	2830.00^{a}_{y}	3146.69^{a}_{x}	3053.93^{a}_{x}	2776.49^{a}
PP_2	1563.33^{a}_{x}	1676.67^{b}_{x}	1040.00^{d}_{y}	1076.67^{d}_{y}	1339.16^{c}
PP_3	1033.31^{b}_{z}	1180.00^{c}_{z}	1593.33^{c}_{y}	2666.89^{b}_{x}	1618.38^{b}
PP_4	893.34^{b}_{z}	1466.91^{b}_{y}	2006.67^{b}_{x}	1880.00^{c}_{x}	1561.73^{b}
N means	1341.23_{z}	1788.40_{y}	1946.67_{xy}	2169.37_{x}	

CV = 10%

(b)

Planting Pattern	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	1923.36^{a}_{y}	2033.33^{a}_{y}	2076.68^{a}_{y}	2733.00^{a}_{x}	2191.59^{a}
PP_2	1180.00^{c}_{y}	1293.94^{b}_{y}	1203.46^{b}_{y}	1996.69^{b}_{x}	1418.23^{b}
PP_3	1593.00^{b}_{y}	1323.14^{b}_{yz}	1133.94^{b}_{z}	1843.33^{b}_{x}	1473.34^{b}
PP_4	1593.33^{b}_{x}	1294.31^{b}_{y}	1293.46^{b}_{y}	1170.00^{c}_{y}	1337.78^{b}
N means	1572.42_{y}	1486.18_{y}	1401.89_{y}	1935.76_{x}	

CV = 9%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	1861.32	1605.24

F test V
ns

4.2.6.2: Yield component: No of pods per Bean Plant

Intercropping beans with both Annette and B53 gave no nitrogen or planting pattern significant effects (Tables 35a and b).

Table 35: Effect of planting patterns and nitrogen levels on the number of pods per bean plant intercropped with (a) Annette and (b) B53 potato varieties (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	8.33	9.33	12.67	10.33	10.17
PP_2	10.00	9.33	13.00	10.67	10.75
PP_3	9.67	10.33	10.67	9.00	9.92
PP_4	8.67	9.67	9.67	9.00	9.25
N means	9.17	9.67	11.50	9.75	

CV = 10%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	9.33	12.67	8.00	9.67	9.92
PP_2	9.00	11.00	9.33	10.33	9.92
PP_3	10.67	10.67	9.00	9.00	9.84
PP_4	9.67	10.00	8.33	9.33	9.33
N means	9.67	11.09	8.67	9.58	

CV = 11%

Within each column means followed by the same superscripts a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	10.02	9.75

F test V
ns

4.2.6.3: Yield Component: Number of seeds per pod of Bean plant

The two treatments of nitrogen application and planting patterns had no significant effect on number of seeds per pod of bean plant when intercropped with either Annette or B53 potato varieties (Tables 36a and b).

Table 36: Effect of planting patterns and nitrogen levels on number of seeds per pod of bean plant intercropped with (a) Annette and (9b) B53 potato varieties (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	5.67	6.67	6.67	6.33	6.34
PP_2	5.00b	6.33	6.00	5.00	5.58
PP_3	5.33	6.00	6.00	5.67	5.75
PP_4	5.67	5.67	6.67	5.67	5.92
N means	5.42	6.20	6.34	5.67	

CV = 21%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	5.67	6.00	6.33	6.33	6.08
PP_2	5.00	5.00	6.33	5.00	5.17
PP_3	5.33	6.33	6.00	5.43	5.76
PP_4	5.33	6.00	6.33	5.33	5.75
N means	5.33	5.83	6.25	5.52	

CV = 14%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

	V_1	V_2
Variety means	5.90	5.69

	V
F test	ns

4.2.7: Effect of planting pattern and nitrogen levels on potato yield (tonnes/ha) and yield components

4.2.7.1: *Fresh Potato Tuber Yield (tonnes/ha)*

Both the Annette and B53 potato varieties gave the main effects of nitrogen and planting patterns as well as their interactions as being significant. The Annette potato variety had higher yields from same hill planting than the yields obtained from the other three planting patterns at 0 and 37.5kg/ha. At 37.5kg/ha sole crop, alternate row and alternate hill patterns were also not different. At the higher nitrogen levels of 75kg/ha and 112.5kg/ha, the sole crop and alternate row yields were statistically similar and higher than same hill and alternate hill yields . The latter two were also the same. Nitrogen response was such that under sole crop, the low nitrogen levels of 0 and 37.5kg/ha were not significantly different but they were significantly lower than the yield obtained when the nitrogen levels were increased to 75 and 112.5kg/ha. In alternate row pattern, significant increases occured when the nitrogen levels were increased from 0 to 37.5 and from 37.5kg/ha to 75kg/ha. No increases were noted at all the nitrogen levels in alternate hill planting patterns while under same hill planting pattern the first two nitrogen levels of 0 and 37.5kg/ha gave significantly higher yields than the next two levels of 75 and 112.5kg/ha (Table 37a). The B53 variety responded by showing higher same hill planting pattern yields than yields of all the other three planting patterns at 0kg/ha nitrogen level. Sole crop and alternate hill planting patterns were not different but they were better than the alternate row pattern yields. Increasing the nitrogen level to 37.5kg/ha gave same sole crop and same hill pattern yields which were statistically higher than the yields of the other two similar patterns of alternate row and alternate hills. The high nitrogen levels of 75 and 112.5kg/ha realised sole crop yields that were higher than yields of the other three similar planting patterns at 75kgN/ha. At 112.5kg/ha same hill planting was lower than alternate hill and alternate row. Planting patterns response to nitrogen application was such that were noted when the nitrogen levels were increased above 37.5kg/ha in sole crop and above 75kg/ha in alternate hill and alternate row planting pattterns. Yield decreases occured when the nitrogen levels were increased from 0 to 37.5kg/ha in alternate hill and from 37.5 to 75 and from 75 to 112.5kg/ha in same hill planting pattern (Table 37b). The varietal differences were significant with Annette variety giving significantly higher yields than yields obtained from B53 variety.

Table 37: Effect of planting patterns and nitrogen levels on fresh potato tuber yield (tonnes/ha) of (a) Annette and (b) B53 potato varieties (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	25.09^{b}_{y}	25.00^{b}_{y}	26.11^{a}_{x}	26.38^{a}_{x}	25.80^{a}
PP2	23.85^{c}_{z}	24.88^{b}_{y}	26.32^{a}_{x}	26.32^{a}_{x}	25.34^{a}
PP3	24.09^{c}_{x}	24.58^{b}_{x}	24.19^{b}_{x}	24.87^{b}_{x}	24.44^{b}
PP4	26.16^{a}_{x}	26.58^{a}_{x}	24.37^{b}_{y}	24.93^{b}_{y}	25.52^{a}
N means	24.80_{y}	25.42_{x}	25.25_{x}	25.63_{x}	

CV = 8%

(b)

Planting Patterns	Nitrogen Levels (KgN/ha) N1	N2	N3	N4	PP means
PP1	24.40^{b}_{y}	25.18^{a}_{y}	26.67^{a}_{x}	26.02^{a}_{x}	25.57^{a}
PP2	23.45^{c}_{y}	23.95^{b}_{y}	24.63^{b}_{xy}	25.08^{b}_{x}	24.28^{b}
PP3	24.49^{b}_{y}	23.80^{b}_{z}	24.33^{b}_{y}	25.34^{b}_{x}	24.49^{b}
PP4	26.44^{a}_{x}	25.59^{a}_{x}	24.88^{b}_{y}	24.29^{c}_{z}	25.30^{a}
N means	24.70_{y}	24.63_{y}	25.12_{x}	25.18_{x}	

CV = 5%

Within each column means followed by the same superscripts (a,b,c) and within each row means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test.

Variety means	V1	V2
	25.21	24.91

F test V
*

4.2.7.2: Number of Tubers per Plant

The two varieties of potato namely Annette and B53 were not affected significantly by the nitrogen and planting pattern treatments. The tuber numbers were also not affected by varietal differences (Tables 38a and b).

Table 38: Effect of planting patterns and nitrogen levels on number of potato tuber per plant of (a) Annette and (b) B53 potato varieties (Season two)

(a)

Planting Patterns	Nitrogen Levels (KgN/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	7.67	8.00	9.33	8.33	8.33
PP_2	8.33	8.33	8.33	8.67	8.42
PP_3	8.67	9.00	9.00	8.67	8.83
PP_4	8.00	8.33	8.33	9.00	8.42
N means	8.17	8.42	8.75	8.67	

CV = 8%

(b)

Planting Patterns	Nitrogen Levels (Kg/ha)				
	N_1	N_2	N_3	N_4	PP means
PP_1	8.67	9.00	9.00	8.33	8.75
PP_2	8.67	8.67	8.33	8.33	8.50
PP_3	8.38	8.33	8.33	8.00	8.26
PP_4	8.38	8.33	8.33	8.00	8.26
N means	8.52	8.58	8.50	8.17	

CV = 10%

Within each column means followed by the same superscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncans Multiple Range test

Variety means	V_1	V_2
	8.50	8.44

F test V

ns

4.2.8: Effect of planting patterns and nitrogen levels on the land equivalent ratio (LER)

There was a significant interation between nitrogen and planting patterns for both potato varieties. In Annette bean intercrop at 0 and 75kgN/ha, same hill planting was statistically similar to alternate hill planting but higher than alternate row planting. There were no differences between alternate row and alternate hill patterns. At 37.5kg/ha same hill LER was higher than LERS of the other two planting patterns while at 112.5kg/ha, alternate row planting out-yielded the other two patterns of alternate hill and same hill. There was no significant LER changes when nitrogen was increased from 0 to 37.5kg/ha for all the three intercrop patterns. A reduction in LER values occured when nitrogen was increased from 37.5 to 75kg/ha with no further change when the nitrogen was increased from 75kg/ha to 112.5kg/ha except in alternate row planting where a significant increase was noted (Table 39a). B53 bean intercrop gave same hill LER values as being significantly higher than those of alternate row and alternate hill patterns at 0 and 37.5kg/ha. The latter two patterns were similar. At 75kg/ha alternate row and alternate hill patterns were not different but had higher LER values than alternate hill planting. The highest nitrogen level of 112.5kg/ha gave alternate hill planting as giving LER values that were higher than those of the other two similar patterns of alternate hill and same hill planting. All the three planting patterns showed a signficant decrease in LER when the nitrogen level was increased from 0 to 37.5kg/ha. Further increases above 37.5kgN/ha showed no change in LER values.

Table 39: The effect of planting patterns and nitrogen levels on the land equivalent ratio (LER) for crop yields (season two) Table (a) Annette and (b) B53 potato/bean intercrop

(a)

Planting patterns	Nitrogen levels (KgN/ha) N_1	N_2	N_3	N_4	PP means
PP_1	-	-	-	-	
PP_2	1.89^{b}_{x}	1.84^{b}_{x}	1.46^{b}_{z}	1.64^{a}_{y}	1.70^{a}
PP_3	1.94^{ab}_{x}	1.91^{b}_{x}	1.52^{ab}_{y}	1.50^{b}_{y}	1.72^{b}
PP_4	2.03^{a}_{x}	2.05^{a}_{x}	1.64^{a}_{y}	1.47^{b}_{y}	1.80^{a}
N means	1.95_{x}	1.93_{x}	1.54_{y}	1.54_{y}	

(b)

Planting patterns	Nitrogen levels (KgN/ha) N_1	N_2	N_3	N_4	PP means
PP1	-	-	-	-	
PP2	1.98^{b}_{x}	1.70^{b}_{y}	1.69^{a}_{y}	1.83^{a}_{xy}	1.80^{a}
PP3	2.00^{b}_{x}	1.70^{b}_{y}	1.59^{b}_{y}	1.50^{b}_{y}	1.70^{b}
PP4	2.27^{a}_{x}	1.83^{a}_{y}	1.70^{a}_{y}	1.67^{b}_{y}	1.87^{a}
N means	2.08_{x}	1.74_{y}	1.66_{y}	1.67_{y}	

Within each column means followed with the same lsuperscripts (a,b,c) and within each row, means followed by the same subscripts (x,y,z) are not significantly different at 5% probability level according to Duncan's Multiple range test.

Variety means	V_1	V_2
	1.74	1.79

F test V
ns

5.0 DISCUSSION

Over both seasons for the two potato varieties of Annette and B53, both the planting patterns and nitrogen had a significant effect on growth and potato yield. All the cases showed that at the low nitrogen levels of 0 and 37.5kg/ha same hill planting gave significantly higher yields and land equivalent ratios than the other two planting patterns of alternate row and alternate hills. This yield advantage could be attributed to the increased intimacy between the two crops enabling potato plants to benefit from nitrogen released from actively fixing and/or dead and decaying legume roots and nodules (De, 1980; Poth *et al.*, 1986). Credibility of this interpretation is boosted by the observation that nodule numbers and weights were higher in same hill intercropping patterns at the beginning of the season (week 4 and 6). Work done using ^{15}N uptake by the roots have indicated that the N-rich legume roots and nodules contribute a susbstantial amount of nitrogen to the associated crop (Poth *et al.*, 1986). According to Hamel *et al* , (1991), this nitrogen transfer from legume to non legume is through mineralization of senescing legume tissues or from release of nitrogenous compounds by legume roots. He further reported that the uptake by the receiver plants of the N excreted by the donor plant root system appears to be closely related to the extent of contact between their plant root systems. On the other hand, differences in competition intensity for the available nitrogen between the two crops could have also brought about the yield differences mainly in terms of influencing nitrogen uptake and fixation. Potato being a heavy feeding crop, according to Durr and Lorenz (1980), could have depleted the nitrogen in the rooting zone hence stimulating the bean plants in association with it to form more nodules for nitrogen fixation. This kind of competition is likely to be greater in a case where the two crops are planted in a very close proximity and may explain the way highest nodule numbers and weights were obtained in same hill pattern compared to the other planting patterns of alternate row and alternate hills at low nitrogen levels of 0 and 37.5kg/ha. Patra *et al.*,(1986), reported in his work with cow-pea-maize intercrop that intercropped legumes have been found to fix significantly higher amounts of nitrogen as compared to sole crop legumes when the two are given the same dose of nitrogen fertilizer Willey (1979) suggested that depletion of nitrogen by the cereal intercropped with the legume causes an increase in nitrogen fixation observed as a stimulation of nodule numbers and weights. Similar observations were made by Rerkasem *et al* (1985) who found that interropping of maize and rice bean (*Vigna umbellata)* increased nitrogen fixation due to competition for soil nitrogen by the maize.

The advantage of close intimancy disappeared at the higher nitrogen levels of 75 and 112.5kg/ha. These higher levels of applied nitrogen gave sole crop and alternate row planting patterns yields that were higher than same hill and alternate hill planting. This change of yield pattern could be attributed to the fact that as the applied nitrogen increases, the response in potato crop is a fast haulm growth (Ngugi, 1972) and this may have increased the intercrop competition for plant resources hence depressing the yields of both potatoes and beans grown as intercrops compared to sole crops. High nitrogen levels in the soil also depresses nitrogen fixation (Herridge, 1982) This may have reduced the posimity benefit even further. Over both seasons the potato dry matter yield from sole crop was significantly higher than for the intercrops over with it to form more nodules for nitrogen fixation. This kind of competition is likely to be greater in a case where the two crops are planted in a very close proximity and may explain the way highest nodule numbers and weights were obtained in same hill pattern compared to the other planting patterns of alternate row and alternate hills at low nitrogen levels of 0 and 37.5kg/ha. Patra *et al.*,(1986), reported in his work with cow-pea-maize intercrop that intercropped legumes have been found to fix significantly higher amounts of nitrogen as compared to sole crop legumes when the two are given the same dose of nitrogen fertilizer Willey (1979) suggested that depletion of nitrogen by the cereal intercropped with the legume causes an increase in nitrogen fixation observed as a stimulation of nodule numbers and weights. Similar observations were made by Rerkasem *et al* (1985) who found that interropping of maize and rice bean (*Vigna umbellata)* increased nitrogen fixation due to competition for soil nitrogen by the maize.

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Bean yields were affected significantly by the planting patterns with sole crop beans out-yielding the intercrops except at 37.5kg/ha nitrogen level where sole beans and beans planted with potatoes in the same hill were not significantly different. This may further explain the fact that the two crops required a starter nitrogen before fixation by the beans can be experienced. According to Harper and Gibson (1984), even legumes utilize substantial amounts of soil nitrate during growth, and under limiting nitrogen conditions, may compete with associated crop. Bean yields responded positively to nitrogen fetilizer application although, higher nitrogen doses tended to depress this parameter in some instances. This implies that bean plants require same starter soil N before they are stable enough to fix their own. Studies on response of sole beans to nitrogen fertilizer application by Cardosso *et al* , (1978); Haag *et al*, (1978) and Keya *et al.*, (1982) have all found significant increases in bean yields with application of nitrogen fertilizer. Furthermore, legumes have been reported to utilize mineral nitrogen in preference to forming nodules and fixing nitrogen (Allos and Bartholomew, 1959). The greatest yield reduction for same hill planting at 112.5kg/ha nitrogen could be attributed to competition for above ground resources mainly because the potatoes haulm growth rate is very high in the presence of abundant nitrogen. The other planting patterns may not have experienced a very intense competition due to the wider interplant spacing. In their case the applied nitrogen may have improved the yield. Kalra and Ganguar (1980), working with maize - cowpea mixtures, found that application of 80 and 120kg/ha nitrogen gave larger seed yields of cowpea than 40kg/ha. Chui (1988) in maize-bean intercrops, also observed increases in intercrop yields with nitrogen application. The bean yield components of pods per plant and seeds per pod followed the same trend as the yield suggesting that the yield was influenced by these components. Chui (1988) observed an increase in pod numbers per plant of beans intercropped with maize when nitrogen was applied. Hagg *et al.*, (1978) reported a significant increase in 100- seed weight when nitrogen was applied and therefore attributed the overall higher bean yields obtained to the two parameters.

Planting pattern affected bean dry matter yield in that sole crop and alternate row yields were significantly higher than those of alternate hill and same hill planting at low nitrogen levels of 0 and 37.5kg/ha. Sole bean outyielded the other planting patterns at the higher nitrogen levels of 75 and 112.5kg/ha. This confirms that there was competition for plant resources such that closer intimacy of same hill and alternate hills as well as faster growth of potatoes at high nitrogen levels did not favour bean dry matter yield when grown as intercrops with potatoes. According to Ngugi (1972) and Dubetz and Bole (1985) potatoes haulm growth respond postively to nitrogen application resulting in very fast growth. Nitrogen application of 75kg/ha and 112.5kg/ha significantly increased sole bean dry matter yields. This increase could be due to the provision of adequate supply of building materials during the vegetative growth and increased photosynthetic efficiency due to lack of competition for available nitrogen, and hence, subsequent increase in total dry matters observed (Andrew and Eck, 1983). Molina (1975) reported that dry matter production of 6 bean cultivars increased with nitrogen application. Dean and Clarke (1980) found significant increases in dry matter in black bean (*Phaseolus vulgaris L.*) from application of nitrogen fertilizer, although N-fertilization consistently depressed introgen fixation.

The overal tuber yield for Annette potato variety was significantly higher than for B53. Closer observation here indicates that at 0kg/ha nitrogen, same hill planting increased the yields of Annette and B53 by 3.8% and 15% respectively in the first season and by 10.1% and 12.5% respectively in the second season compared to alternate row planting. This observation indicates some advantage of using the late maturing potato variety as it may benefit more from the nitrogen released by the bean plants when the two crops are grown in closer intimacy. By staying in the field for a longer time, B53 was able to benefit more from the nitrogen released from the bean plants later in the season, through mineralization of the decaying nodules and senescing beans roots

The land equivalent ratios showed the superiority of intercropping to monocropping in terms of field productivity at all nitrogen levels, although the yield advantages declined with increased nitrogen rates in same hill planting mainly due to increased competition. The competition comes about due to the fast vegetative growth. Similar results were obtained by Ahmed and Rao (1982) in maize/soyabean intercropping. At high nitrogen levels, the LER for same hill intercropping was depressed more than those of alternate row and alternate hill while at the lower nitrogen levels same hill maintained significantly higher LER values than the other two patterns. Therefore the most profitable intercropping pattern in terms of land use efficiency is a situation where beans are intercropped with potatoes in the same hill, especially under low soil nitrogen.

CONCLUSIONS

From the results obtained from this study the conclusions can be drawn when growing the two crops together under low nitrogen soils, it would be worthwhile to grow them in the same hill which is superior to the other planting patterns of alternate row and alternate hills. However higher soil nitrogen levels depress the intimacy advantage due to competition as well as reduced N fixation, In such a case, sole crop or alternate row planting should be preffered. This finding can be of great importance to small scale farmers whose farms are characterised by low fertility conditions due to lack of inputs. It would therefore be advisable for these farmers to plant the two crops together in the same hill so as to exploit the potential nitrogen made available by the bean plants. This yield advantage obtained by growing the two crops in close proximity may have occured due to mingling of the intercrop roots which allowed contact of potato roots with the nitrogen excreting points of the beans and the stimulation of additional nitrogen fixation as a result of increased competition for soil nitrogen by the two crops, observed as higher nodule numbers and weights in same hill planting under low nitrogen conditions.

Intercropping potato and beans requires that the two crops are grown in very close proximity (same hill) and application of nitrogen may not be necessary although, a starter nitrogen of upto

37.5kg/ha may also be of some benefit to the two crops. Other planting patterns if used, may require application of nitrogen of upto 75kg/ha.

A late maturing variety of potatoes is apparently a better candidate for this intercropping system as it seems that most of the nitrogen contributed to potatoes by beans was derived from dead and decomposing bean roots and nodules. For the same reason the earliest maturing bean varieties should be used and planted at the time as late maturing potatoe variety if not earlier.

Recommendations for Further Research

1) The same experiment should be repeated but using potato varieties with very wide differences in maturity time in order to analyse even further the extent to which this kind of benefit from beans is useful. Further analysis can also be done using labelled nitrogen (^{15}N) to find out the approximate percentage of nitrogen that the potato can obtain from the beans.

2) Bean inoculation should also be undertaken to determine whether inoculation can influence the performance of the intercropping system used in this experiment.

3) More bean varieties should be tried under the same experiment to determine whether some varieties would be more useful in terms of nitrogen fixation and tolerance to the NO_3^- and NH_4^+ ions in the soil than others.

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Appendix A: Soil Analysis Results

Field designation	Season one	Season two
Depth cm	0 - 30	0 - 30
Colour	Dark red	Dark red
pH	5.5	5.4
Na m.e. %	0.046	0.043
K m.e. %	0.70	1.08
Ca m.e. %	4.00	6.0
Mg m.e. %	1.90	1.83
Mn m.e. %	1.08	1.46
P ppm	6.8	5.9
N %	0.289 high	0.24 high
C %	1.97	2.21

Appendix B: Weather Data During the Experimental Period:

Year	Month	Total Rainfall Cm	Temperature (°C) Max.	Min.
		Season One		
1993	October	24.6	25.0	13.0
1993	November	200.9	22.7	13.5
1993	December	48.6	22.8	13.8
1994	January	4.9	24.0	13.5
1994	February	5.8	26.2	13.2
1994	March	5.6	22.2	12.4
		Season Two		
1994	May	209.0	22.5	13.4
1994	June	25.6	21.6	12.4
1994	July	17.8	18.9	10.9
1994	August	3.8	17.8	10.5
1994	September	14.3	18.4	11.5
1994	October	4.9	22.9	12.4

Appendix 1: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) 4 weeks after emergence (season one) (a) Annette and (b) B53 Potato varieties

Table (a)

Source	SS	df	MS	F	P
Blocks	140510.69	2	70255.34	3.79	0.034*
Main Effects					
Planting patterns (PP)	186760.26	3	62253.42	3.36	0.034ns
Nitrogen (N)	458840.98	3	152946.99	8.26	0.004**
Interaction PP X N	59944.79	9	6660.53	0.36	0.45ns
Error	555570.58	30	18519.02		
Total	1401627.30	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	42096.49	2	21048.25	1.16	0.26*
Main Effects					
Planting patterns (PP)	247539.75	3	82513.25	4.55	0.047ns
Nitrogen (N)	336724.83	3	112241.61	6.19	0.007***
Interaction PP X N	302065.98	9	33562.78	1.06	1.85ns
Error	544201.07	30	18140.03		
Total	1562628.12	47			

Appendix 2: ANOVA Table for Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) 6 weeks after emergence (season one)

(a) Annette and (b) B53 Potato varieties

Table (a)

Source	SS	ss	MS	F	P
Blocks	222971.30	2	111485.65	2.15	2.13*
Main Effects					
Planting patterns (PP)	213403.36	3	71134.45	1.37	1.46ns
Nitrogen (N)	408016.38	3	136005.46	2.03	0.004ns
Interaction PP X N	594566.04	9	66062.89	1.28	0.45ns
Error	1553363.52	30	51778.78		
Total	2992320.60	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	15796.74	2	7898.37	0.40	0.67ns
Main Effects					
Planting patterns (PP)	99692.21	3	33230.74	1.69	0.19ns
Nitrogen (N)	469965.91	3	156655.30	7.95	0.17ns
Interaction PP X N	468137.38	9	52015.27	2.64	0.22ns
Error	590944.92	30	19698.16		
Total	1644537.16	47			

Appendix 3. ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) 8weeks after emergence (season one) (a) Annette and (b) B53 Potato varieties

Table (a)

Source	SS	df	MS	F	P
Blocks	34238.04	2	17119.02	1.09	1.35ns
Main Effects					
Planting patterns (PP)	2927175.72	3	975725.24	61.94	1***
Nitrogen (N)	372013.26	3	124004.42	7.87	0.0005***
Interaction PP X N	552467.47	9	61385.27	3.9	0.0023**
Error	472589.82	30	15752.99		
Total	4358484.31	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	28204.98	2	14102.49	1.44	0.25*
Main Effects					
Planting patterns (PP)	335172.94	3	111724.31	11.43	0***
Nitrogen (N)	103288.86	3	34429.62	3.52	0.027*
Interaction PP X N	910656.53	9	101184.06	10.34	0***
Error	293325.48	30	9777.52		
Total	1670648.8	47			

Appendix 3. ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) 8weeks after emergence (season one) (a) Annette and (b) B53 Potato varieties

Table (a)

Source	SS	df	MS	F	P
Blocks	34238.04	2	17119.02	1.09	1.35ns
Main Effects					
Planting patterns (PP)	2927175.72	3	975725.24	61.94	1***
Nitrogen (N)	372013.26	3	124004.42	7.87	0.0005***
Interaction PP X N	552467.47	9	61385.27	3.9	0.0023**
Error	472589.82	30	15752.99		
Total	4358484.31	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	28204.98	2	14102.49	1.44	0.25*
Main Effects					
Planting patterns (PP)	335172.94	3	111724.31	11.43	0***
Nitrogen (N)	103288.86	3	34429.62	3.52	0.027*
Interaction PP X N	910656.53	9	101184.06	10.34	0***
Error	293325.48	30	9777.52		
Total	1670648.8	47			

Appendix 4: ANOVA Table for Effect of Planting Patterns and Nitrogen levels on Bean Dry yield 4 weeks after emergence when intercropped with (a) Annette (b) B53 potato variety (season one)

Table (a)

Source	SS	DF	MS	F	P
Blocks	241139.23	2	120569.61	3.71	0.036*
Main Effects					
Planting patterns (PP)	108959.46	3	36319.82	1.42	1.36*
Nitrogen (N)	409108.98	3	136369.66	4.19	0.014*
Interaction PP X N	164008.17	9	18223.13	0.56	0.82ns
Error	975560.93	30	32518.70		
Total	1898776.77	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	74726.62	2	37363.31	1.29	0.29*
Main Effects					
Planting patterns (PP)	225222.18	3	75074.06	2.58	0.072*
Nitrogen (N)	688455.70	3	229485.23	7.90	0.005***
Interaction PP X N	164293.06	9	18254.78	0.63	0.76ns
Error	871745.10	30	29058.17		
Total	2024442.66	47			

Appendix 5: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on bean Dry Matter Yield (kg/ha) 6 weeks after emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	DF	MS	F	P
Blocks	239428.43	2	119714.21	2.73	0.081**
Main Effects					
Planting patterns (PP)	422964.74	3	143088.25	3.26	0.035*
Nitrogen (N)	1595728.52	3	531909.51	12.13	0.00***
Interaction PP X N	724306.28	9	80478.48	1.84	0.010*
Error	1315523.39	30	43850.78		
Total	4304251.36	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	241144.25	2	120572.12	1.12	1.34ns
Main Effects					
Planting patterns (PP)	347214.07	3	115738.02	1.08	0.037*
Nitrogen (N)	1193143.22	3	397714.41	3.70	0.022*
Interaction PP X N	1295701.05	9	143966.78	1.34	0.026*
Error	3228171.74	30	107605.72		
Total	6305374.33	47			

Appendix 6. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on Bean Dry Matter Yield (kg/ha) 8 weeks After Emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	15720.77	2	7860.34	0.082	0.92ns
Main Effects					
Planting patterns (PP)	739112.90	3	246370.97	2.58	0.0072*
Nitrogen (N)	2370576.98	3	790192.33	8.29	0.004***
Interaction PP X N	461332.55	9	162370.28	1.70	0.13*
Error	2859618.12	30	95320.60		
Total	7446361.32	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	94536.41	2	47268.20	0.39	0.68ns
Main Effects					
Planting patterns (PP)	1214543.50	3	404847.83	3.31	0.033*
Nitrogen (N)	6806707.90	3	2268902.63	18.55	0.000***
Interaction PP X N	2514141.57	9	279349.06	2.28	0.044*
Error	3670146.51	30	122338.22		
Total	14300075.89	47			

Appendix 7. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of nodules per Bean Plant 4 weeks After Emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	6656.63	2	3328.31	1.34	0.28ns
Main Effects					
Planting patterns (PP)	10898.42	3	3632.81	1.46	0.0024*
Nitrogen (N)	32399.08	3	10799.69	4.34	0.012*
Interaction PP X N	30943.75	9	3438.19	1.38	0.0024*
Error	74495.38	30	2483.18		
Total	155393.26	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	8295.79	2	4147.90	2.48	0.10ns
Main Effects					
Planting patterns (PP)	22819.23	3	7606.41	4.55	0.0097**
Nitrogen (N)	32672.90	3	10890.97	6.51	0.0016**
Interaction PP X N	40117.02	9	4457.45	2.66	0.021*
Error	50197.54	30	1673.25		
Total	154102.48	47			

Appendix 8. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule numbers per bean plant at 6 weeks after emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	4857.13	2	2428.56	1.31	0.28ns
Main Effects					
Planting patterns (PP)	35131.75	3	11710.58	6.34	0.0019**
Nitrogen (N)	33386.08	3	11128.69	6.02	0.0024**
Interaction PP X N	36137.42	9	4015.27	2.17	0.054*
Error	55442.88	30	1848.10		
Total	164955.24	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	19699.29	2	9849.65	10.31	0.0004***
Main Effects					
Planting patterns (PP)	15736.17	3	5245.39	5.49	0.0040**
Nitrogen (N)	11550.17	3	3850.06	4.03	0.016*
Interaction PP X N	33763.00	9	3751.44	3.93	0.0022**
Error	28670.04	30	955.67		
Total	109418.67	47			

Appendix 9. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule numbers per Bean Plant at 8 weeks After Emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	219.04	2	109.52	0.044	0.96ns
Main Effects					
Planting patterns (PP)	12048.75	3	4136.25	1.67	0.0019*
Nitrogen (N)	9715.58	3	3238.53	1.31	0.0029*
Interaction PP X N	22596.25	9	2510.69	1.01	0.0045*
Error	74360.29	30	2478.68		
Total	119299.91	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	4261.54	2	2130.77	2.79	0.078*
Main Effects					
Planting patterns (PP)	40307.06	3	13435.69	17.57	0.000***
Nitrogen (N)	17376.73	3	5792.24	7.57	0.0006***
Interaction PP X N	26647.02	9	2960.78	3.87	0.0024**
Error	22941.13	30	764.70		
Total	111533.48	47			

Appendix 9. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule numbers per Bean Plant at 8 weeks After Emergence when intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	219.04	2	109.52	0.044	0.96ns
Main Effects					
Planting patterns (PP)	12048.75	3	4136.25	1.67	0.0019*
Nitrogen (N)	9715.58	3	3238.53	1.31	0.0029*
Interaction PP X N	22596.25	9	2510.69	1.01	0.0045*
Error	74360.29	30	2478.68		
Total	119299.91	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	4261.54	2	2130.77	2.79	0.078*
Main Effects					
Planting patterns (PP)	40307.06	3	13435.69	17.57	0.000***
Nitrogen (N)	17376.73	3	5792.24	7.57	0.0006***
Interaction PP X N	26647.02	9	2960.78	3.87	0.0024**
Error	22941.13	30	764.70		
Total	111533.48	47			

Appendix 10. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant of beans at 4 weeks After Emergence intercropped with (a) Annette and (b) B53 Potato varieties

Table (a)

Source	SS	df	MS	F	P
Blocks	44.11	2	22.05	0.79	0.46*
Main Effects					
Planting patterns (PP)	214.29	3	71.43	2.56	0.073*
Nitrogen (N)	342.69	3	114.23	4.10	0.15**
Interaction PP X N	226.29	9	25.14	0.90	0.54*
Error	836.33	30	27.88		
Total	1663.71	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	101.46	2	50.73	2.93	0.069*
Main Effects					
Planting patterns (PP)	97.39	3	32.46	1.87	0.16*
Nitrogen (N)	129.82	3	43.27	2.30	0.078*
Interaction PP X N	281.12	9	31.24	1.80	0.11*
Error	520.14	30	17.34		
Total	1129.93	47			

Appendix 11. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant) of beans intercropped with (a) Annette and (b) B53 Potato varieties at 6 weeks After Emergence (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	69.55	2	34.78	1.69	0.20*
Main Effects					
Planting patterns (PP)	204.21	3	68.07	3.31	0.033*
Nitrogen (N)	278.28	3	92.76	4.52	0.009**
Interaction PP X N	388.72	9	43.20	2.10	0.061**
Error	616.04	30	20.53		
Total	1556.90	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	156.46	2	78.23	9.36	0.0007***
Main Effects					
Planting patterns (PP)	101.43	3	33.81	4.04	0.016*
Nitrogen (N)	65.82	3	21.94	2.62	0.0069*
Interaction PP X N	146.39	9	16.27	1.95	0.0083*
Error	250.83	30	8.36		
Total	720.93	47			

Appendix 12. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule wt (g/plant) of Bean intercropped with (a) Annette and (b) B53 Potato varieties at 8 weeks After Emergence (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	11.39	2	5.70	1.23	0.31ns
Main Effects					
Planting patterns (PP)	267.41	3	89.14	19.18	0.00***
Nitrogen (N)	61.05	3	20.35	4.38	0.011*
Interaction PP X N	156.06	9	17.34	3.73	0.0031**
Error	139.43	30	4.65		
Total	635.34	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	14.06	2	7.03	2.00	0.153ns
Main Effects					
Planting patterns (PP)	56.35	3	18.78	5.34	0.0045**
Nitrogen (N)	34.92	3	11.64	3.31	0.033*
Interaction PP X N	326.82	9	36.31	10.33	0.00***
Error	105.45	30	3.52		
Total	537.60	47			

Appendix 13. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on Bean Yield (kg/ha) intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	993382.63	2	496691.32	1.96	0.16*
Main Effects					
Planting patterns (PP)	31914697.62	3	10638232.54	41.94	0.00***
Nitrogen (N)	2989659.32	3	996553.11	3.92	0.018*
Interaction PP X N	4512784.41	9	501420.49	1.98	0.0078*
Error	7609987.53	30	253666.25		
Total	48020511.51	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	923127.54	2	461563.77	2.90	0.071ns
Main Effects					
Planting patterns (PP)	13492934.22	3	4497644.74	28.27	0.003***
Nitrogen (N)	3259801.20	3	1086600.40	6.82	0.0012**
Interaction PP X N	1951485.01	9	216831.67	1.36	0.002*
Error	4773470.83	30	159115.69		
Total	24400818.80	47			

Appendix 14. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of pods per Bean plant intercropped with (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	9.04	2	4.52	0.99	0.38ns
Main Effects					
Planting patterns (PP)	196.83	3	65.61	14.44	0.000***
Nitrogen (N)	88.17	3	29.39	6.47	0.0017**
Interaction PP X N	176.33	9	19.59	4.31	0.0011**
Error	136.29	30	4.54		
Total	606.66	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	30.78	2	15.19	3.99	0.029*
Main Effects					
Planting patterns (PP)	247.90	3	82.63	21.69	0.000***
Nitrogen (N)	52.06	3	17.35	4.56	0.0096**
Interaction PP X N	238.69	9	26.52	6.96	0.000***
Error	114.29	30	3.81		
Total	683.32	47			

Appendix 15. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on potato fresh tuber Yield (tonns/ha) of (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	10.65	2	5.32	6.12	0.0059**
Main Effects					
Planting patterns (PP)	36.88	3	12.29	14.13	0.000***
Nitrogen (N)	32.79	3	10.93	12.56	0.000***
Interaction PP X N	18.30	9	2.03	2.34	0.039*
Error	26.11	30	0.87		
Total	124.73	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	1.77	2	0.89	0.85	0.44ns
Main Effects					
Planting patterns (PP)	47.35	3	15.78	15.11	0.00***
Nitrogen (N)	12.92	3	4.31	4.12	0.015*
Interaction PP X N	41.50	9	4.61	4.42	0.001***
Error	31.33	30	1.04		
Total	134.87	47			

Appendix 16. ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of tubers per potato plant (a) Annette and (b) B53 Potato varieties (season one)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.040	2	0.021	0.0025	0.99ns
Main Effects					
Planting patterns (PP)	29.17	3	9.72	1.15	0.34ns
Nitrogen (N)	6.17	3	2.06	0.24	0.86ns
Interaction PP X N	28.67	9	3.19	0.38	0.94ns
Error	252.63	30	8.42		
Total	316.68	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	5.29	2	2.65	0.47	0.63ns
Main Effects					
Planting patterns (PP)	1.75	3	0.58	0.10	0.96ns
Nitrogen (N)	34.92	3	11.64	2.06	0.13ns
Interaction PP X N	64.58	9	7.18	1.27	0.29ns
Error	169.38	30	5.65		
Total	275.92	47			

Appendix 17: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) of (a) Annette and (b) B53 Potato varieties 4 wks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	689.64	2	344.82	0.82	0.45ns
Main Effects					
Planting patterns (PP)	2897.45	3	965.82	2.28	0.099ns
Nitrogen (N)	18209.96	3	6069.99	14.36	0.000***
Interaction PP X N	6258.74	9	695.42	1.65	0.15ns
Error	12680.86	30	422.70		
Total	40736.66	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	2886.36	2	1443.18	2.61	0.090ns
Main Effects					
Planting patterns (PP)	1782.41	3	594.14	1.08	0.37ns
Nitrogen (N)	15670.78	3	5223.59	9.46	0.000***
Interaction PP X N	14780.37	9	1642.26	2.97	0.12ns
Error	16567.42	30	552.25		
Total	51687.35	47			

Appendix 18: ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on Potato Dry Matter Yield (kg/ha) of (a) Annette and (b) B53 Potato varieties 6 wks After Emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	4087.52	2	2043.76	1.10	0.34ns
Main Effects					
Planting patterns (PP)	44586.23	3	14862.08	8.03	0.0004***
Nitrogen (N)	254178.70	3	84726.23	45.77	0.00***
Interaction PP X N	123335.22	9	13703.91	7.40	0.00**
Error	55531.72	30	1851.96		
Total	481719.39	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	5429.85	2	2714.93	0.98	0.39ns
Main Effects					
Planting patterns (PP)	31884.73	3	10628.24	3.82	0.02*
Nitrogen (N)	192546.67	3	64182.22	23.09	0.000***
Interaction PP X N	19600.56	9	2177.84	0.78	0.006*
Error	83376.69	30	2779.22		
Total	332838.51	47			

Appendix 19: ANOVA Tables on Effect of Planting Patterns and Nitrogen level on potato dry matter yield (kg/ha) of (a) Annette and (b) B53 potato varieties 8 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	50610.38	2	25305.19	4.65	0.018*
Main Effects					
Planting patterns (PP)	12699.64	3	4233.21	0.78	0.82*
Nitrogen (N)	235312.21	3	78437.40	14.40	0.00***
Interaction PP X N	132521.13	9	14724.57	2.70	0.020*
Error	163384.71	30	5446.16		
Total	594528.07	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	19429.31	2	2714.65	1.43	0.26ns
Main Effects					
Planting patterns (PP)	37407.06	3	12469.02	1.83	0.006*
Nitrogen (N)	631551.56	3	210517.19	30.93	0.00***
Interaction PP X N	172739.62	9	19193.29	2.82	0.016*
Error	204192.30	30	6806.41		
Total	1065319.85	47			

Appendix 20: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on potato dry matter yield (kg/ha) of (a) Annette (b) B53 Potato varieties 10 weeks after emergency (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	81305.72	2	40652.86	7.85	0.0018**
Main Effects					
Planting patterns (PP)	139818.04	3	46606.01	9.00	0.0002***
Nitrogen (N)	627314.55	3	209104.85	40.37	0.00***
Interaction PP X N	167496.85	9	18610.76	3.59	0.0039**
Error	155399.80	30	5179.99		
Total	1171334.96	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	16400.64	2	8200.32	0.67	0.52ns
Main Effects					
Planting patterns (PP)	187222.79	3	62407.60	5.10	0.0057**
Nitrogen (N)	5461230.52	3	182043.51	14.88	0.00***
Interaction PP X N	167897.34	9	18655.26	1.52	0.013*
Error	367092.51	30	12236.42		
Total	1284743.80	47			

Appendix 21 ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 4 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	964.95	2	482.48	1.77	0.19ns
Main Effects					
Planting patterns (PP)	1640.04	3	546.68	2.00	0.13ns
Nitrogen (N)	12641.30	3	4213.77	15.44	0.00***
Interaction PP X N	4029.64	9	447.74	1.64	0.15ns
Error	8186.05	30	272.87		
Total	27461.98	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	1522.13	2	761.06	3.42	0.046*
Main Effects					
Planting patterns (PP)	2399.30	3	799.77	3.59	0.25ns
Nitrogen (N)	6292.82	3	2097.61	9.42	0.20ns
Interaction PP X N	8865.34	9	985.04	4.42	0.100ns
Error	6683.71	30	222.79		
Total	25763.30	47			

Appendix 22: ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on dry matter yield of bean plants (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 6 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	5256.65	2	2628.32	1.04	0.36ns
Main Effects					
Planting patterns (PP)	41925.30	3	13975.10	5.54	0.0038**
Nitrogen (N)	155488.97	3	51829.66	20.54	0.000**
Interaction PP X N	51598.95	9	5733.22	2.27	0.044*
Error	75719.58	30	2523.85		
Total	329985.55	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	1435.44	2	717.72	0.22	0.80ns
Main Effects					
Planting patterns (PP)	63463.80	3	21154.60	6.62	0.0015**
Nitrogen (N)	67761.23	3	22587.08	7.07	0.001**
Interaction PP X N	42626.74	9	4736.30	1.48	0.0019*
Error	95896.00	30	3196.53		
Total	271183.21	47			

Appendix 23 ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on dry matter yield (kg/ha) of bean plants intercropped with (a) Annette and (b) B53 potato varieties 8 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	5421.96	2	2710.98	0.59	0.056ns
Main Effects					
Planting patterns (PP)	181061.13	3	60353.71	13.03	0.00***
Nitrogen (N)	549306.88	3	183102.29	39.52	0.00***
Interaction PP X N	157961.78	9	17551.31	3.79	0.0028**
Error	138997.91	30	4633.26		
Total	1032749.66	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	32141.10	2	16070.55	1.85	0.048ns
Main Effects					
Planting patterns (PP)	223856.73	3	74618.91	8.58	0.012*
Nitrogen (N)	466345.91	3	155448.64	17.88	0.000***
Interaction PP X N	57398.22	9	6377.58	0.73	0.0041*
Error	260835.66	30	8694.52		
Total	1040577.62	47			

Appendix 24 ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on dry bean matter yield (kg/ha) intercropped with (a) Annette and (b) B53 potato varieties 10 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	66019.11	2	33009.56	6.51	0.0045**
Main Effects					
Planting patterns (PP)	526929.72	3	175643.24	34.63	0.00***
Nitrogen (N)	205203.47	3	68401.16	13.49	0.000***
Interaction PP X N	95559.51	9	10619.72	2.09	0.0063ns
Error	152158.22	30	5071.94		
Total	1045870.03	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	49791.84	2	24895.92	4.02	0.028*
Main Effects					
Planting patterns (PP)	377847.50	3	125949.17	20.36	0.00***
Nitrogen (N)	761084.95	3	253694.98	41.01	0.00***
Interaction PP X N	89209.67	9	9912.19	1.60	0.016*
Error	185591.08	30	6186.37		
Total	1463525.04	47			

Appendix 25 ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of nodules per bean plant when intercropped with (a) Annette and (b) B53 potato varieties 4 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	93.17	2	46.58	0.64	0.53ns
Main Effects					
Planting patterns (PP)	4358.83	3	1452.94	20.06	0.00***
Nitrogen (N)	5070.83	3	1690.28	23.34	0.00***
Interaction PP X N	2781.00	9	309.00	4.27	0.0012**
Error	2172.83	30	72.43		
Total	14476.66	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	610.13	2	305.06	2.57	0.093ns
Main Effects					
Planting patterns (PP)	2963.06	3	987.69	8.32	0.0004***
Nitrogen (N)	5308.73	3	1769.58	14.91	0.000***
Interaction PP X N	2027.35	9	230.26	1.94	0.0084*
Error	3560.54	30	118.68		
Total	14514.81	47			

Appendix 26 ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of nodules per bean plant when intercropped with (a) Annette and (b) B53 potato varieties 6 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	415.04	2	207.52	1.95	0.16ns
Main Effects					
Planting patterns (PP)	2244.75	3	748.25	7.03	0.001**
Nitrogen (N)	1196.42	3	398.81	3.74	0.02*
Interaction PP X N	3178.75	9	353.19	3.32	0.0064**
Error	3194.96	30	106.50		
Total	10229.92	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	102.13	2	51.06	1.65	0.80ns
Main Effects					
Planting patterns (PP)	1179.08	3	393.03	12.69	0.016**
Nitrogen (N)	1213.21	3	404.40	13.06	0.015**
Interaction PP X N	1455.75	9	161.75	5.22	0.0036**
Error	929.08	30	30.97		
Total	4879.23	47			

Appendix 27: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of nodules per bean plant when intercropped with (a) Annette and (b) B53 potato varieties 8 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	227.54	2	113.77	0.97	0.39ns
Main Effects					
Planting patterns (PP)	66.75	3	22.25	0.19	0.90ns
Nitrogen (N)	83.75	3	27.92	0.24	0.0080ns
Interaction PP X N	548.08	9	60.90	0.52	0.85ns
Error	3521.79	30	117.39		
Total	4447.91	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	39.54	2	19.77	0.18	0.83ns
Main Effects					
Planting patterns (PP)	57.33	3	19.11	0.18	0.91ns
Nitrogen (N)	127.17	3	42.39	0.39	0.76ns
Interaction PP X N	822.83	9	91.43	0.85	0.58ns
Error	3237.79	30	108.93		
Total	4284.66	47			

Appendix 28: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on number of nodules per bean plant when intercropped with (a) Annette and (b) B53 potato varieties 10 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	261.54	2	130.77	1.65	0.21ns
Main Effects					
Planting patterns (PP)	912.42	3	304.14	3.84	0.19ns
Nitrogen (N)	463.42	3	154.47	1.95	0.14ns
Interaction PP X N	377.42	9	41.94	0.53	0.85ns
Error	2373.13	30	79.10		
Total	4387.93	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	614.54	2	307.27	2.98	0.066ns
Main Effects					
Planting patterns (PP)	350.56	3	116.85	1.13	0.92ns
Nitrogen (N)	310.35	3	103.45	1.00	0.013ns
Interaction PP X N	438.35	9	48.71	0.47	0.88ns
Error	3092.13	30	103.07		
Total	4706.43	47			

Appendix 29 : ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties 4 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.60	2	0.30	1.03	0.37ns
Main Effects					
Planting patterns (PP)	16.76	13	5.59	19.10	0.00***
Nitrogen (N)	30.18	3	10.06	34.39	0.00***
Interaction PP X N	8.16	9	0.91	3.10	0.0094**
Error	8.78	30	0.29		
Total	64.48	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	3.02	2	1.51	2.66	0.086ns
Main Effects					
Planting patterns (PP)	9.45	3	3.15	5.55	0.0038**
Nitrogen (N)	22.56	3	7.52	3.25	0.000***
Interaction PP X N	6.21	9	0.69	1.22	0.012*
Error	17.02	30	0.57		
Total	58.26	47			

Appendix 30: ANOVA Tables for Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant) of beans intercropped with (a) Annette and (b) B5 potato varieties 6 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	1.90	2	0.95	0.99	0.38ns
Main Effects					
Planting patterns (PP)	11.98	3	3.99	4.19	0.014*
Nitrogen (N)	23.75	3	7.92	8.29	0.0004***
Interaction PP X N	28.78	9	3.20	3.35	0.0060**
Error	28.63	30	0.95		
Total	95.04	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	1.01	2	0.51	0.60	0.55ns
Main Effects					
Planting patterns (PP)	26.47	3	8.82	10.50	0.072**
Nitrogen (N)	24.05	3	8.02	9.57	0.0001***
Interaction PP X N	24.96	9	2.77	3.30	0.0074*
Error	25.13	30	0.84		
Total	101.62	47			

Appendix 31: ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties 8 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.23	2	0.12	0.33	0.64ns
Main Effects					
Planting patterns (PP)	0.11	3	0.035	0.097	0.94ns
Nitrogen (N)	0.33	3	0.11	0.31	0.0097ns
Interaction PP X N	1.00	9	0.11	0.31	0.90ns
Error	10.70	30	0.36		
Total	12.47	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	0.081	2	0.040	0.67	0.52ns
Main Effects					
Planting patterns (PP)	0.057	3	0.019	0.31	0.81ns
Nitrogen (N)	0.023	3	0.075	1.24	0.0031ns
Interaction PP X N	0.31	9	0.035	0.57	0.81ns
Error	1.82	30	0.061		
Total	2.29	47			

Appendix 32: ANOVA Tables on Effect of Planting Patterns and Nitrogen levels on nodule wt. (g/plant) of beans intercropped with (a) Annette and (b) B53 potato varieties 10 weeks after emergence (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.09	2	0.045	1.25	0.30ns
Main Effects					
Planting patterns (PP)	0.31	3	0.10	2.90	0.051ns
Nitrogen (N)	0.089	3	0.030	0.82	0.0049ns
Interaction PP X N	0.13	9	0.015	0.40	0.92ns
Error	1.08	30	0.036		
Total	1.71	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	0.47	2	0.23	6.54	0.0044**
Main Effects					
Planting patterns (PP)	0.12	3	0.040	1.12	0.36ns
Nitrogen (N)	0.12	3	0.039	1.08	0.0037ns
Interaction PP X N	0.13	9	0.014	0.40	0.93ns
Error	1.08	30	0.036		
Total	1.92	47			

Appendix 33: ANOVA tables for Effect of Planting pattern and nitrogen levels on bean yield (kg/ha) when intercropped with (a) Annette and (b) B53 potato varieties (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.29	2	0.14	1.36	0.27ns
Main Effects					
Planting patterns (PP)	25.81	3	8.60	82.15	0.00***
Nitrogen (N)	22.10	3	7.37	70.35	0.00***
Interaction					
PP X N	9.04	9	1.00	9.59	0.00***
rror	3.14	30	0.10		
otal	60.38	47			

Table (b)

rce	SS	df	MS	F	P
ks	0.92	2	0.46	2.36	0.11ns
Effects					
g patterns (PP)	4.77	3	1.59	8.18	0.0004***
n (N)	12.69	3	4.23	21.77	0.00***
on					
	2.43	9	0.27	1.39	0.0024*
	5.83	30	0.19		
	26.64	47			

Appendix 34: ANOVA tables for Effect of Planting pattern and nitrogen levels of pods per bean when intercropped with (a) Annette and (b) B53 potato varieties (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	3.38	2	1.69	0.50	0.45ns
Main Effects					
Planting patterns (PP)	32.23	3	10.74	3.18	0.04ns
Nitrogen (N)	45.56	3	15.19	4.49	0.01ns
Interaction PP X N	83.65	9	9.29	2.75	0.01ns
Error	101.29	30	3.38		
Total	266.11	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	22.63	2	11.31	2.83	0.035*
Main Effects					
Planting patterns (PP)	30.00	3	10.00	2.50	0.033ns
Nitrogen (N)	40.83	3	13.61	3.40	0.036ns
Interaction PP X N	46.50	9	5.17	1.72	0.13ns
Error	120.04	30	3.00		
Total	260.00	47			

Appendix 35: ANOVA tables for Effect of Planting patterns and nitrogen levels on number of seeds per pod of bean plant when intercropped with (a) Annette and (b) B53 potato varieties (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	27.56	2	13.78	9.50	0.12*
Main Effects					
Planting patterns (PP)	2.73	3	0.91	0.63	0.60ns
Nitrogen (N)	6.50	3	2.17	1.49	0.019ns
Interaction PP X N	10.02	9	1.11	0.77	0.65ns
Error	43.50	30	1.45		
Total	90.31	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	5.04	2	2.52	2.44	0.10ns
Main Effects					
Planting patterns (PP)	12.25	3	4.08	3.96	0.17ns
Nitrogen (N)	10.42	3	3.47	3.36	0.31ns
Interaction PP X N	13.25	9	1.47	1.43	0.22ns
Error	30.96	30	1.03		
Total	71.92	47			

Appendix 36: ANOVA tables for Effect of Planting patterns and nitrogen levels of Potato fresh tuber yield (tonns/ha) of (a) Annette and (b) B53 potato varieties (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	1.60	2	0.80	1.47	0.25ns
Main Effects					
Planting patterns (PP)	6.94	3	2.31	4.24	0.013*
Nitrogen (N)	9.45	3	3.15	5.78	0.0030**
Interaction PP X N	15.92	9	1.77	3.24	0.0072**
Error	16.35	30	0.55		
Total	50.26	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	0.62	2	0.31	0.49	0.61ns
Main Effects					
Planting patterns (PP)	4.05	3	1.35	2.16	0.011*
Nitrogen (N)	10.42	3	3.48	5.55	0.0037**
Interaction PP X N	10.63	9	1.18	1.89	0.0093**
Error	18.72	30	0.63		
Total	44.44	47			

Appendix 37: ANOVA tables on Effect of Planting pattern and nitrogen levels on number of tubers per plant of (a) Annette and (b) B53 potato varieties (season two)

Table (a)

Source	SS	df	MS	F	P
Blocks	0.13	2	0.063	0.033	0.97ns
Main Effects					
Planting patterns (PP)	9.50	3	3.17	1.67	0.20ns
Nitrogen (N)	3.50	3	1.17	0.61	0.61ns
Interaction PP X N	25.67	9	2.85	1.47	0.19ns
Error	57.21	30	1.91		
Total	96.11	47			

Table (b)

Source	SS	df	MS	F	P
Blocks	1.04	2	0.52	0.27	0.76ns
Main Effects					
Planting patterns (PP)	8.22	3	2.74	1.43	0.25ns
Nitrogen (N)	13.23	3	4.41	2.30	0.08ns
Interaction PP X N	26.35	9	2.92	1.52	0.18ns
Error	57.63	30	1.92		
Total	106.47	47			