# EFFECTS OF NITROGEN AND SPACING ON THE GROWTH AND YIELD OF POTATO (*Solarium tuberOSUM* I.)

*BY*

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DECLARATION

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

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CERTIFICATION

This thesis entitled 'EFFECTS OF NITROGEN AND SPACING ON THE GROWTH AND YIELD OF POTATO (Solanum tuberosum L.) by Miss Beatrice Anim MBAH, meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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## ABSTRACT

Data are reported from an experiment conducted under rainfed conditions in 1984 at the University Farm of Ahmadu Bello University, Samaru, Zaria, to study the effect of nitrogen and spacing. on the growth and yield of potato (Solanum tuberosum L.).

Three levels of nitrogen (0, 60 and 120 kgN/ha), three plant spacings (20, 30 and 40cm) and two potato varieties (B9462-1 and BR3-18) were used. Results revealed that nitrogen remarkably increased the number of leaves, axillary branches, stems, stolons and tubers, plant height, leaf,:stem and tuber dry weights, leaf area index and tiet assimile rate. It also increased the total yield and the proportion of tubers of size greaterr than 40mm and less than 40mm diameter. Spacing had no visible effect on the number of leaves, plant height, dry matter and percent; crude protein. Leaf stem and tuber dry weights were increased by increasing spacing between plants. The leaf area index, total yield, number of tubers per unit area, yield of tubers falling into the two grades considered were increased by close spacing.

The yield of the two varieties, differed markedly, variety B9462-1 yielding about twice as much as variety BR63-18. For each spacing variety BR63-18 produced significantly more number of tubers than the other variety.

The two varieties showed a significant linear response to nitrogen and spacing.

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Chapter 1

# INTRODUCTION

## 1.1 Origin and Spread

The potato (Solanum tuberosum L.) belongs to the family Solanaceae. It is produced normally from tubers except in breeding programmes when seeds are used.

The name 'potato' is believed to have originated from the Indian name 'Batatas' (August et al, 1964). This crop originated in the high Andes region of Peru and Polivia. Spanish conquistadors introduced it to Europe in the late sixteenth century and the crop was then internationalized (Anonymous, 1980). Although it originated in the tropics, it has got its main agricultural impact in the temperate zone.

## 1.2 Adaptation

Most research on potato have been devoted to their production and use in temperate climate, but in recent decades, increasing attention has been paid to the crop in tropical regions (Montaldo, 1970). Recent ideas on its adaptation in the tropics have been reviewed by Simmonds (1971) and French (1972). Substantial work has been done in India on the potato in tropical ecosystems (Upadhya et al, 1972).

In West Africa, potato has never been a crop of great importance as the arable land at high altitude which is suitable for potato growth is limited. It has however been grown at Aburi and Mampong in Ghana (Doku, 1966) and in Nigeria, on the Jos, Mambila and Biu plateaux at altitudes of between 600-1300m (Suchomel 1971 and Suchomel and Bot 1976). Successful cultivation has also been reported in the central African Republic, Upper Volta (Burkina Faso) and Cameroon (Coursey and Booth, 1977).

## 1.3 Introduction in Nigeria

The potato is a relatively new crop to the Nigerian farmer. It was introduced into the Jos area during 1920s by European miners (Suchomel and Bot, 1976). The location of the northern limit of root crop economy in Nigeria borders around Jos plateau where owing to the high altitude (1220 to 1370m), low temperatures (12$^{o}$C to 15$^{o}$C) and low humidity during the wet growing season of May to August, this area forms a congenial environment for growing potato (Obigbesan, 1977). Potato is also grown commercially around Zaria, the Biu plateau and Mambila plateau with altitudes of 600m, 650m and 1400m, respectively.

The Jos potato industry which initially developed quite spontaneously from the private gardening of expatriate miners (Coursey and Booth, 1977), has supplied a substantial quantity of Nigeria's potato requirement for over 50 years.

## 1.4 Importance

Due to its high nutritive value, potato has great prospects in supplementing food requirements and improving nutritional status of the people. In terms of calorific production, potato is the fourth most important staple, it however has the highest capacity in terms of protein production due to its high yield per hectare (Idusogie, 1971). The biological value of its protein compares favourably with that of eggs. It is also an excellent source of vitamins B and C as well as some minerals. The potato is a short duration crop and can fit very well into the present cropping systems in Nigeria.

## 1.5 Production and Yield

The total world production of potato in 1980 was 226 million tonnes, grown on an area of 13.7 million hectares with an average yield of 12.5t/ha (FAO, 1980). Yields recorded under tropical conditions are exceedingly variable and low from 5t/ha to 10t/ha (Coursey and Booth, 1977).

## 1.6 Production Constraints in Nigeria

Several factors that constrain production of potato and cause low yields have been identified. In Nigeria, apart from the high incidence of disease, agronomic knowledge is very scanty, for example, time of

planting. The correct plant population and nutrient requirement have not been adequately worked out. It has been observed by some workers that planting potatoes in the tropics at populations of about 30,000 to 40,000 plants/ha (a normal spacing for temperate climate), the plants do not close over between rows. There is therefore a need for spacing trials because a lot of energy is wasted on bare ground and this contributes in raising soil temperatures.

The varieties grown in Nigeria are now referred to as local. They are in fact an accumulated mixture of imported varieties which have now so fully adapted that their original identity is lost. At the Irish Potato centre, National Root Crops Research Institute (NRCRI), Vom, Jos, several trials are now going on using some exotic varieties in order to develop an agronomic production package that will suit the climatic conditions of some of the producing areas in Nigeria.

At present, Nigerian consumers do not seem to have any choice on what they get from the market, production is still low and potato is considered as a food for the rich. With increasing hectarage being put under potato production and better agronomic practices being passed over to farmers by researchers, more and better quality potatoes will appear in the markets. The quality aspects include tuber shape and size, skin and flesh colour, shallowness and number of eyes,

firmness after cooking, discoloration of tubers when raw, etc. Any agronomic production package to increase yield will have to take quality of produce into consideration as the potato industry grows. For example fertilization of the potato crop is an aspect that can be manipulated to produce different quality tubers.

There is need of much information on the agronomic practices for potato production that the existing and prospective potato growers in Nigeria need in order to boost production.

The objective of this study therefore was to study the effect of nitrogen, spacing and their interactions on the growth, yield and quality of two varieties of potato in Zaria under savanna ecological zone.

Chapter 2

# REVIEW OF LITERATURE

Much work has been done on spacing and fertilization on different potato varieties, but there have been continued interest in this subject for the primary reason that the enviromental conditions of the localities where potato is grown differ a lot.

## 2.1 Response to Fertilizers

Potato responds well to the application of mineral fertilizers. According to Beukema and van Der Zaag (1979), a crop yielding 30 t/ha take from the soil during growth 150kg N, 60kg $P_2O_5$ and 50kg $K_2O$ from one hectare of land. The same authors mentioned that for normal soils the ratio N: $P_2O_5$ : $K_2O$ in the fertilizer should be 1:1:2 but other ratios are required under special conditions. They also added that on soils rich in potassium, the amount of this element can be reduced.

The potato is a potash loving plant and responds to generous applications of this plant food which ranks next to nitrogen in importance. When used in adequate proportions with heavy dressing of nitrogen, it prevents excessive growth and makes the leaves to have thicker texture and higher colour, and reduces susceptibility to blight (Wallace, 1951). Potassium

is reputed to have influence on crop yield and quality, and is responsible for the translocation of carbohydrates to storage organs (Obigbesan, 1971). With the prevailing non-intensive farming conditions, Heathcote (1973) observed that K deficiency is not a serious problem in most of the savanna zone of Nigeria. Initial fertilizer trials on potatoes in Vom did not give any response to K application (O.P. Ifenkwe, Private communication), and therefore in all their fertilizer trials K has been applied as a blanket form to balance other nutrients.

## 2.2 Effect of Nitrogen Fertilization

Nitrogen is the most important of the plant foods supplied to potato. Despite the fact that it has more influence on yield than any other element, the correct proportions of phosphate and potash must be used in conjunction with it.

Potato plants deficient in nitrogen are usually relatively sparse with upright growth. They are pale in colour and grow slowly with leaves which yellow progressively after flower drop. Too much nitrogen on the other hand produces excessively vigorous plants which are dark green in colour, with flowering, fruiting and tuberization being delayed, while the vegetative phase is prolonged. This is also known to impair the cooking quality of the tubers which turn black when cooked (Wallace 1951).

All the nitrogenous fertilizers except urea and cyanamide contain nitrogen either in ammonical or nitrate forms or their mixture. Young plants are known to make use of ammonia nitrogen, but under field conditions, the quantity used by the crops in the ammonia form is very small compared to the amount of nitrogen absorbed as nitrates (Anonymous, 1965). Most of the nitrogen contained in inorganic residues, ammonia fertilizers, urea compounds and other organic sources of nitrogen must be changed to nitrate before it can be utilized by the potato (Anonymous, 1981). Birecki (1963) reported that direct contact of nitrogen fertilizers with the tubers reduces both yield and starch content of tubers and inhibits emergence, especially at low soil moisture content. Where nitrogen is applied in a situation of water stress, both tuber formation and bulking rate have been reported to be adversely affected (Wellings, 1972).

2.2.1 Effect of nitrogen on haulm growth

Gray (1974) observed a decrease in competition among sprouts when inorganic nitrogen was applied to tuber pieces. He also noted an effect of N on time of maturity; plants given 0-50kg N/ha matured seven days earlier than those given 100-150 kgN/ha, and 25 days earlier than those given 201-251 kgN/ha. Dyson and Watson (1971) showed that application of 200-250kg N/ha

can prolong foliage growth by up to six weeks in a wet season compared to crops given no N. Generally a more rapid development of a light intercepting surface (leaves) results in a higher total dry matter without loss of efficiency up to leaf area index (LAI) values of about four (Khurana and Mclaren, 1982). To maximise this total dry matter production, the canopy has to be maintained by keeping plants free from water stress, pests and diseases. Allen and Scott (1980) had reported potato blight as being probably the most important factor determining the persistence of the potato canopy. Nitrogen is generally believed to increase the susceptibility to blight (Wallace, 1951).

Nitrogen increased leaf number and growth from an early stage and LAI reached a maxima of 2.5-3.0 with the largest amounts of nitrogen and 1.0 with no nitrogen (Dyson and Watson, 1971). They also found that LAI decreased later in the season with increased nitrogen. Gunasena and Harris (1969) and Dyson and Watson (1971) observed that increasing the rate of nitrogen affected yield components, with the leaf and stem yields responding to the highest rate of nitrogen from a fairly early stage of growth, tuber yield not responding significantly until the end of the growing season. There is usually a tendency in the early stages of growth for the response to very high rates of nitrogen to be negative.

### 2.2.2 Effect of Nitrogen on tuber formation and development

Abdel-Maksoud et al., (1978) and Svensson (1962) found an increase in number of stems, stolons and tubers per plant with increase in nitrogen level. Tuber forming efficiency was greatest with low nitrogen levels in young plants but increased with nitrogen level in older plants. In another experiment, Abdel-Maksoud et al. (1978) observed that application of nitrogen increased foliage dry weight, tuber weight and tuber: top ratio, but decreased tuber starch content.

It has been reported that the main effect of nitrogen fertilization is to increase the number of tubers, and allowing this increased number to grow just as rapidly as a smaller number would without nitrogen fertilizer (Hanley et al., 1965). These authors further noted that total yields of tubers rose to a maximum at or just after 95% haulm death and then declined irrespective of fertilizer treatment. The DM% reached its maximum when the haulm died.

Ivins and Bremner (1965) observed that in the potato plant, there is competition for assimilates between foliage and tubers, and the balance can swing in one direction or the other depending on the treatment received. Van Burg (1967) and Gunasena and Harris (1969) reported that soon after initiation, movement of assimilates to tubers tend to be

dominant but increasing nitrogen increased the proportion of leaf and stem in the total DM and decreased the proportion of tubers. Dyson and Watson (1971) noted that nitrogen did not delay tuber initiation but slowed early growth of tubers, while van Burg (1967) reported that increasing the rate of applied nitrogen stimulates the growth of haulms and delays the start of tuber initiation. In water culture experiments, Sattelmacher and Marshner (1979) observed that interruption of the nitrogen supply via roots induces tuberization and their nitrogen analysis showed that there was no correlation of the nitrogen content of the plant and tuberization. The results were discussed in terms of hormonal changes within the roots and shoots caused by the differences in the nitrogen nutritional status of the roots.

2.2.3 Effect of nitrogen on yield

Yields obtained generally depend on the time of tuber initiation and on the rate and duration of tuber bulking. Some workers reported increased tuber yields with increasing levels of nitrogen up to 150 kgN/ha, following the law of diminishing returns, and that the increase in yield was mainly because of increase in tuber size as was supported by the yield of large size tubers Allen and Scott (1980), Anonymous (1980) and Khurana et al. (1984).

2.2.4 Effect of nitrogen on quality of potatoes

Lomakè and Dubrovin (1977) observed that increasing the rate of nitrogen fertilization decreased tuber starch content but increased the proportion of marketable tubers. Tahtinen (1978) had similar findings and noted that the highest rate of nitrogen weakened the flavour of tubers, depressed their mealiness and slightly increased their discoloration when raw.

Several workers (Henley et al., 1965, Gunasena and Harris, 1969, Dyson and Watson, 1971; Laughlin, 1971; Talley 1983 and White and Sanderson, 1983) have reported an increase in DM up to a certain level with increase in nitrogen after which there may be a decrease in DM. Results have also shown an increase in nitrogen percentage in DM with an increase in nitrogen fertilization (Dyson and Watson, 1971).

Hunnius et al. (1980) reported that for ware potatoes, a nitrogen fertilization rate of 100-120 kg/ha was not detrimental in respect of compounds determining quality; starch, protein or vitamin C content, eating quality or susceptibility to damage. In their experiment, even 130kg N/ha did not show any decrease in starch yields in cultivars with high starch content and high nitrogen requirements. At much larger fertilizer rates than normally used (placed 560kg N, 245kg $P_2O_5$ and 475 kg $K_2O$/ha at planting), Widdowson et al. (1974) had extraordinary yields of 112t/ha and

found that these rates did not impair the market grade, DM content and chipping quality of the potatoes. However, White and Sanderson (1983) recommended the nitrogen requirement for the production of processing tubers as 130kg/ha for potatoes in Prince Edward Island.

Bleasdale and Thompson (1969) observed that the highest rates of nitrogen fertilizer applied increased the nitrogen content of tubers by about 50%, had little or no effect on the P and K contents, and was associated with a decrease in DM content from 22.6% to 21.0%. Increasing nitrogen was also associated with a decrease from 20 to 12% in the proportion of tubers breaking down and doubling in the number showing marked after-cooking blackening. These results are not in agreement with that of Hunnius et al. (1980) and Widdowson et al. (1974).

On fresh weight basis the protein content of potato is fairly low but the protein content in the DM is often compared with that of grain (Westerland, 1969). In his experiment using different varieties and five nitrogen levels (0-300kg N/ha), the results showed that the content of crude protein increased with increased nitrogen applied.

White et al. (1974) noted that increasing the rates of nitrogen and potash fertilizers increased total yields and the percentage of 'A' size tubers of potato, but increased nitrogen rates slightly decreased

the specific gravity of tubers.

## 2.3 Effect of Spacing in Potato

For potato, yield is a product of the vegetative growth and the agronomic yield is the product of the number of plants per unit area, the mean weight of tubers per plant and the proportion of tubers reaching the ware size. All of these could be affected by increasing or reducing the spacing of seed tubers Holliday (1960) gave the definition of unit plant population in potato as the individual sprout which grows from the seed tuber to produce an independent plant. The true plant population is thus the product of the number of sprouts developed per tuber. The variety, size and treatment will each affect the number of sprouts developed. Svensson (1962) reported that the intra-row (hill to hill) spacings will depend upon the distance between rows, hill size, variety and growing conditions.

### 2.3.1 Effect of spacing on haulm growth

Allen and Wurr (1974) gave the above ground stem count as a satisfactory method of recording density in potato. Competition between individual stems arising from a single planting position or hill may be expected to play a major part in determining the size and nature of a potato crop (Moorby, 1967), this can also be true of interhill competition. The total haulm weight is a function of the number of stem and the size of leaves

borne on these stems. The greatest part in any increase in tuber dry weight comes from accumulation of carbohydrates and there is competition between the tubers for carbohydrates from the haulm, an explanation for the decrease in mean tuber weight with increasing stem number per hill. The amount of leaf tissue available to supply carbohydrates to each tuber is decreased as stem number per hill is increased.

Svensson and Naglicke (1975), using spacings of main 10cm and 20cm, found that hills spaced 10cm apart had lower number of mainstems than hills spaced 20cm. This was attributed to harder competition in this stand. The number of stolons was higher in the 20cm stands and the number of tubers per main stem was higher in the thinner stand. They also found that the haulm area per hill was higher for 10cm stands than for 20cm stands. Ifenkwe and Allen (1978) reported that increasing plant density reduced the number of axillary branches and their leaves per plant, dry weight of leaves, stems, underground parts and tuber dry weight per unit area. They further observed good relationships between tuber yields and number of above - ground stems which led them to support the use of stems as the basic unit of density in this crop. Svensson (1962) noticed an increase in number of stolons with increasing spacing.

Sale (1973a) and Sale (1973b) suggested that a practical approach to increasing yields may be to increase the numbers of tubers which develop per unit area by increasing the plant density, and encouraging

early haulm growth.

2.3.2 Effect of spacing on tuber formation and development

The results of Sale (1973a) and Sale (1973b) were in agreement with the hypothesis that assimilation in the potato depends primarily on the "sink" strength of the developing tubers which is determined in the 2-3 weeks following the onset of initiation. Similar observations have been made by Wright (1955). Bremner and Taha (1966) and Moorby (1967) Bremner et al. (1961) found little difference between spacing treatments as regards tuber initiation or in persistence of the foliage. After the initial stage, the number is being maintained moreorless although many tubers do not progress beyond this point. However, the duration of bulking, a function of time of tuber initiation and time of haulm senescence has been found to be affected by spacing (Bremner and Taha, 1966). They observed that the bulking rate per hectare in 45cm and 60cm spacings were similar, thereby suggesting that the difference between them must have been due to a difference in duration of bulking.

2.3.3 Effect of spacing on yield

Findlay and Sykes (1938), Murr (1974) and White et al. (1976) reported that increase in spacing produced a decrease in the yields of seed and chat grades, and increase in the yield and in the percentage (by weight)

of the large ware and in the size of the individual tubers of this grade. Findlay and Sykes (1938) pointed out that the reduction in the yield of small tubers and the increases in yield of large-ware and in the size of individual large-ware tubers indicate that an essential consequence of increasing spacing was to increase the average size of tubers as a whole. The increase in the number and size of the tubers with wide spacing did not compensate for the reduction in number of plants and therefore there was a reduction in the total yield as spacing distance was increased.

Choudhari (1958) and Choudhari and Choudhari (1958) indicated that highest yields were obtained with tuber size of 3.75cm diameter and spacing of 75 x 30cm. In their own study, Caesar and Ganesan (1964) observed that the highest yield resulted from close spacing (45 x 40cm) but the greatest return in relation to quantity of seed tubers required was from spacing 25 - 35cm between plants (45cm in between rows). The highest yield of ware tubers in high-yielding and low-yielding trials were from spacings of 60 x 40cm and 60 x 35cm, respectively. White et al. (1976) however did not find any effect of increased spacing on total yields. Several authors including Findlay and Sykes (1938), Bremner et al. (1961), Caesar and Genesan (1964) Iritami et al. (1972) Hruska and Pflung (1976) and Igbal (1982), generally have reported an increase in total yield per plant and yield per unit

area as the spacing distance was decreased.

Thompson and Taylor (1974) found an initial increase in yield with increase in plant population, tending to become constant at higher densities. They suggested that the responses of average tuber weight, number of tubers per stem and the tuber number per unit area to changing density may be explained by the fact that at low densities where competition for light would be minimal, and weight of tubers/unit area would be well below the potential of a crop with a complete canopy and could be considered to be comprised of tubers whose weight was near the maximum for the genotype in that particular environment. In trials carried out at Vom, Jos, tuber yields increased significantly with decreasing spacing within the row, 30cm spacing giving the highest yields averaged overall seed sizes, though the differences were not significant (NRCRI Annual report 1979/80).

Wiersema (1981) summarized that higher plant density leads to increased yield up to a certain point, reduced average tuber size and reduced multiplication rate of potatoes.

2.3.4 Effect of spacing on Tuber Quality

Tuber size and dry matter content are determinants of suitability, especially for dehydration and canning. Potatoes for dehydration require both a mean DM content

and a low variation of individual tuber DM contents about the mean in order to achieve efficient production (Wurr and Allen, 1974). It has been noted that the principal difficulty in interpretation of DM% values from samples of tubers produced by different planting densities is that any comparisons are likely to be influenced by the frequency distribution of tuber sizes.

Bremner et al. (1961), Bremner and Taha (1966), and Inuzuka (1979) found that the proportion of total produce falling into the ware grade increased as spacing distance increased. This effect has best been considered in light of tuber number/unit area, though tuber numbers/plant increased as spacing distance increased. The closely spaced plants have a considerable advantage in tuber numbers/unit area, leading to more intense inter-tuber competition and restriction of tuber size. More larger tubers are produced at low stem densities, presumably because the higher number of tubers/stem is more than compensated for by additional photosynthate made available to each stem.

Bleasdale and Thompson (1969) reported that increasing plant population led to an increase in tuber DM content and tubers of 2-3cm had low DM content than tubers of 4.5-5.5cm size. They stated that this effect might be explained by accepting that high plant densities deplete the moisture status of the ridges far more than low densities. Wurr and Allen (1974) however observed that at early lifts,

treatments with high stem densities gave tubers with higher DM% than low densities but at later lifts there was an increased tendency for low stem densities to give higher DM% as a consequence of the greater number of larger tubers produced.

Increase in DM content has been associated with increase in the disintegration of tubers when cooked. Bleasdale and Thompson (1969) observed that small tubers for canning from high population are more prone to breakdown than tubers of similar size from more normal spacings that might have been used to characterise the cooking quality of the variety. Whole potatoes for canning should be 2.0-4.0cm grade size and meet certain requirements of quality attribute, such as colour, texture and breakdown (Bleasdale and Thompson, 1969). Tubers of the required specification can be obtained either from crops grown from high densities or by harvesting at an immature stage of growth (Bleasdale and Thompson 1969, Gray, 1972). Nelson (1967), Bleasdale and Thompson (1969) and Gray (1972) have all noted that high populations generally resulted in slightly higher total yields and a greater number of small tubers which have a lower DM content.

Van Burg (1967) observed an increase in specific gravity of tubers with increasing plant density, while White et al. (1974) found no effect on the specific gravity of potato. Bleasdale and Thompson (1969) found

that the nitrogen content of tubers was influenced by plant spacing, decreasing with decreasing spacing between hills.

## 2.4 Varietal Differences

Potato varieties differ greatly in total yield of DM, vine size, date of maturity and leaf type. Inspite of these differences, it has been dificult trying to measure their rate of $CO_2$ absorption/unit area of leaf as this influences the rate of DM accumulation. Chapman and Loomis (1953) reported that the magnitude of such differences if they exist must be small.

Usually the purpose of introducing new varieties is to obtain crops that give optimal yields and quality and have adequate resistance against pests and diseases under prevailing conditions. Certain varieties are resistant to the disease late blight (Phytophthora infestans). After death of haulm due to late blight, increase in yield ceases (Hanley et al., 1965) and several weeks of possible production is lost. Any treatment that will cause a crop to reach its maximum yield earlier will result in less destruction by blight. In addition to agricultural characteristics, the purpose for which the potato is grown is also important in deciding which varieties to grow. In Holland, for first earlies and earlies, early maturing characteristics are important while to grow potato for use later in the year, the variety must have good storage qualities and

not sprout too easily (Anonymous, 1984).

Allen and Scott (1980) reported that many varieties are capable of producing and maintaining for much of the season a leaf surface which can intercept at least 85% of the incident radiation. They further noted that the major effect of variety on leaf growth and thereby on yield of potato is likely on the rate at which a complete leaf cover can be attained. So varieties which have a high optimum stem density should have an advantage in early leaf cover over varieties grown at lower stem densities, given that rates of emergence and expansion of individual leaves were the same.

Certain potato varieties flower and fruit profusely under certain conditions. Proudfoot (1965) observed that flowering and fruiting by the potato plant have a depressing effect on tuber yield. In one of his treatments in which normal flowering and berry development was allowed, five plants out of twelve plants gave a greater yield of berries than tubers and the tuber yield was highly significantly affected by permitting plants to form berries. He also noticed that yields were greatly reduced after flowering, showing that flowering itself can have an effect on tuber production. For this reason, flowering and fruiting in any potato variety should be considered as an undesirable character where high yields of tubers is the main reason for production. Such characters are only beneficial for breeding purposes.

The end use of potato tubers also affects the choice of variety. Those suitable for chips should fry to golden brown colour and remain crisp for a reasonable time after cooking while for mashed potatoes well-flavoured floury tubers that can be made into light puree are preferable. For industrial processing, some varieties are more suitable than others.

## 2.5 Interactions

### 2.5.1 Nitrogen x spacing interaction

Rodlaender and Keesman (1966) observed a favourable interaction between plant spacing and nitrogen fertilization. They found that tuber yields increased with plant density up to 70,000 to 100,000 plants/ha and that with dense plantings a decrease in yield was found when no N was supplied. An increase in N supply was most effective at high plant densities especially after a long growing season. Such favourable interaction of N supply and plant density on yield was usually not obtained in early plantings.

Van Burg (1967) also reported an interaction between plant density and nitrogen. An increase in the level of nitrogen, at a planting density of 40,000 tubers led to a slight decrease in yield while at higher planting densities, there was a positive response to nitrogen and yield increased with increasing planting density. In another report, at all spacings used, increasing rates of

N and P from 0-186kg N and P each/ha resulted in a 4-fold increase in yield, but no specific interactions were found between spacing and applied fertilizer, nor were there any significant response to decreased spacing (Anonymous 1981).

2.7.2 Spacing x variety interaction

Wurr (1974) working with two main crop potato varieties observed no significant interactions between spacing and variety but indicated that as the tuber grade size increased, the two varieties responded differently towards increasing population. He pointed out that it was not appropriate to compare varieties by planting them all at the same spacing since the number of stems produced by each tuber differs according to variety and suggested that a more precise assessment of potato would be made by comparing varieties at the same stem density or at the optimum density for each variety over a number of size grades. In Prince Edward Island two important potato varieties have been given spacing recommendations of 30-45cm for Russet Burbank and 20-28cm for kennebec (White and Anderson, 1983). This is because of the differences in growth habit of both varieties which makes them to respond differently to various spacings.

2.7.3 Nitrogen x variety interaction

With different varieties studied, Westerland (1969) observed that Grata which received the same N treatment

es Bintje had higher content of crude protein than Bintje. The protein yield was reported to be about the same for both varieties but the total sum of amino acids was lower in Grata than Bintje. Khurana et al. (1984) found a linear response to N upto 180kg/ha for cultivar Kufri Sindhuri which matures in 120 days and suggestsdthat another cultivar Kufri Chandramuki which matures in 90 days should have different fertilizer requirements. In an experiment on N fertilization of Polish potato varieties, Pirecki and Kaczoreck (1964) found that varieties do respond differently to changes in N level and Roztropowicz and Fotyma (1978) suggested that N rates should be adjusted to the variety grown and the soil and environmental factors.

Chapter 3

# MATERIALS AND METHODS

## 3.1 Experimental Site

The experiment was carried out at the Ahmadu Bello University Farm, Samaru, Zaria. (11°11' N, 07° 38 E and 686m above sea level) in the Northern Guinea Savanna zone, during 1984 rainy season. Soil from the experimental site was analysed for its physical, mechanical and chemical constituents, and the data are presented in Appendix 1. Meteorological information for Samaru during the experimental period is recorded in Appendix 2.

## 3.2 Growing Season

The growing season for potato was normal in respect of rainfall distribution after about a week of no rain after planting. The temperatures were a bit too high thus favouring haulm growth and delaying tuber growth (Appendix 2).

## 3.3 Treatments

Varieties:

(1) B 9462-1

(2) BR 63-18

Spacing (intra-row)

(1) 20cm

(2) 30cm

(3) 40cm

Nitrogen level

(1) 0 kg N/ha

(2) 60 kg N/ha

(3) 120 kg N/ha

There were a total of 18 treatments. Variety B9462-1 is an early maturing variety with fast initial growth and yielding higher than variety BR63-18 which is late maturing. The fast growth phase of variety BR63-18 comes later in the season and is accompanied by profuse flowering and fruiting.

The three intra-row spacings 40cm, 30cm and 20cm, give plant populations of 33,330, 44,440 and 66,660 plants per hectare respectively.

## 3.4 Experimental Layout

Treatments were arranged in a randomized complete block design with a factorial arrangement and replicated four times. A gross plot comprised of four ridges each 6m long and 75cm apart giving an area of $18m^2$. The net plot comprised the two inner ridges (size $9m^2$). Samples were collected from the two outer ridges while the inner ridges were left for final yield analysis.

## 3.5 Cultural Practices

### 3.5.1 Land preparation and fertilizer application

The field was ploughed, disc-harrowed and then made into ridges 75cm apart.

Single superphosphate (18% $P_2O_5$) and muriate of potash (60% $K_2O$) fertilizers were applied to the entire field uniformly before ridging at rates of 100kg $P_2O_5$ and 30kg $K_2O$ per hectare, respectively. Nitrogen was applied as calcium ammonium nitrate (26% N) at rates of 0, 60 and 120 kg N/ha as per the treatments. This was placed at about 2.5cm deep and about 10cm away from the seed tubers.

3.5.2 Planting

The tubers with very viable eyes were planted on 31 May and 1 June, 1984 at the spaces as per treatment. Tubers were placed singly in holes about 5cm deep. Three weeks after planting, number of plants/plot were counted and gaps due to non-emergence were replanted.

3.5.3 Crop protection

Weeding was done thrice at 3, 5 and 8 weeks after planting using a hand hoe.

Seven weeks after planting the field was sprayed at fortnightly intervals with Dithane M 45 at the rate of 3kg/ha for the control of potato blight (Phytophthora infestans).

The crop was earthed up at 5 and 8 weeks after planting.

### 3.5.4 Harvesting

At harvest, total number of plants in the net plot was counted. Harvesting was done using the garden fork. All tubers from the net plot were picked up carefully labelled and taken to the laboratory for further observations.

## 3.6 Data Collection

### 3.6.1 Assessment of plant characters

Samples were collected from 3 weeks after emergence at weekly intervals. At each growth analysis sampling, two plants from the outer two rows of each plot were taken randomly, dug with a garden fork, placed in labelled sacks and taken to the laboratory for detailed observations. In the laboratory, the underground parts were washed carefully in water taking care not to lose the root structure.

Detailed observations were recorded on number of stem, length of stem (from ground level), number of leaves and axillary branches, number of stolons and tubers. A growth from an axillary bud which showed visible stem elongation was considered an axillary branch. Any stolon swelling which was twice the diameter of the stolon was recorded as a tuber in this investigation.

### 3.6.2 Dry weights

Plants were separated into leaves, stems, underground parts (stolons, stems, roots) and tubers for each sample. These were dried for 48 hours at 70°C. For variety BR63-18 the flowers and berries were dried separately and weighed. The dry weights of the various parts were added up to get the total dry weight of the plant.

### 3.6.3 Leaf area and leaf area index

The leaf area meter (Portable Area Meter Mode L1 - 3000) was used to measure the leaf area fortnightly, the leaf area index was calculated by dividing the leaf area by the land area occupied by the plant.

### 3.6.4 Net assimilation rate (NAR)

This was determined using formula:

$$NAR = \frac{1}{LA} \cdot \frac{dw}{dt}$$

where LA = leaf area

dw = change in dry weight between two samplings.

dt = change in time between two samplings.

### 3.6.5 Tuber yield and grading

At final harvest, total number of tubers per plot was counted and weighed. Yield of diseased tubers was noted.

The tubers were graded into two categories- tuber greater than 40mm in diameter (sellable yield) and those less than 40mm in diameter (small tuber yield). This was done using a 40mm grid. The number of tubers in each grade was counted and recorded.

### 3.6.6 Dry matter, starch and crude protein content of tubers

Sub-samples were taken for the assessment of tuber DM, starch and crude protein content. These analyses were carried out in the Food Science and Technology Laboratory of I.A.R, Samaru.

For % DM, tubers were washed, mashed, weighed and then dried for 4 hours at 105°C after which they were weighed again.

The starch content of tubers was determined colorimetrically as described by Allen et al. (1974).

The total nitrogen content of tubers was determined using the micro-kjeldahl method. This was used to estimate the crude protein content.

## 3.7 Analysis of Data

All data were subjected to statistical analysis by using Duncan's multiple range test to compare treatment means.

Chapter 4

# RESULTS

## 4.1 Growth Characters

### 4.1.1 Number of leaves

The number of leaves, the first sign of growth of a plant kept increasing up to eight weeks after emergence (W.A.E.) and thereafter they declined (Table 1). Nitrogen has played an important role in the formation of leaves. Up to six W.A.E. increasing nitrogen level from 0 to 60 kg/ha did not increase the number of leaves per plant. It was only when the level of nitrogen was raised to 120kg/ha was the number of leaves increased over no nitrogen. At seven and eight WAE both 60 and 120kg/ha levels being at par were significantly superior to 0kgN/ha level in increasing the number of leaves.

Formation of leaves was not influenced much by different spacings, however in the later stage of growth closer spacing produced less number of leaves.

There was no significant difference between the two varieties so far as this character is concerned up to eight WAE. At nine WAE, variety BR63-18 had significantly more leaves than variety B9462-1.

Interactions were found to be non-significant.

Table 1: Mean number of leaves per plant of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 29.9 | 47.9 | 70.7 | 112.0 | 138.2 | 176.8 | 148.4 |
| 60 | 32.9 | 49.2 | 78.2 | 124.5 | 165.3 | 213.4 | 149.6 |
| 120 | 33.8 | 52.0 | 83.8 | 131.3 | 172.0 | 222.1 | 149.3 |
| SE (±) | 1.25 | 1.23 | 2.76 | 5.25 | 6.30 | 8.35 | 8.76 |
| LSD (0.05) | NS | 3.43 | 7.65 | 14.55 | 17.47 | 23.14 | NS |
| Spacing (cm) | | | | | | | |
| 40 | 32.0 | 46.9 | 80.5 | 123.0 | 166.7 | 208.2 | 156.6 |
| 30 | 32.0 | 48.5 | 76.0 | 123.8 | 163.1 | 204.6 | 147.9 |
| 20 | 32.6 | 46.8 | 76.2 | 120.9 | 145.7 | 199.5 | 142.2 |
| SE (±) | 1.25 | 1.23 | 2.76 | 5.25 | 6.30 | 8.35 | 8.76 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | NS |
| Variety | | | | | | | |
| B9462-1 | 31.2 | 48.4 | 78.1 | 123.9 | 157.8 | 203.3 | 131.7 |
| BR63-18 | 33.2 | 46.4 | 77.0 | 121.8 | 159.3 | 204.9 | 166.1 |
| SE (±) | 1.02 | 2.25 | 1.01 | 4.29 | 5.15 | 6.82 | 7.15 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | 19.82 |

4.1.2 Number of axillary branches

From four to nine W.A.E., application of nitrogen, either 60 or 120kg/ha significantly increased the number of axillary branches per plant over no nitrogen level (Table 2). There was significant difference between the two higher levels of nitrogen only at five W.A.E., i.e. the higher the level of nitrogen the more was the number of axillary branches.

Except at four W.A.E. when closest and widest spacings produced lowest and highest number of axillary branches respectively, spacings played a non-significant role in influencing this character.

Variety BR63-18 produced more number of axillary branches than the other variety, B9462-1, but the first one was significantly superior to the other only at the fourth and fifth W.A.E.

There was a significant interaction effect between nitrogen and variety on the number of axillary branches at four W.A.E. For all nitrogen levels, variety B9462-1 produced similar number of axillary branches. With variety BR63-18, 60 and 120kg N/ha levels were at par, but were superior to 0 kgN/ha as regards the production of axillary branches (Table 3).

Table 2: Mean total number of axillary branches of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks after emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 2.8 | 4.6 | 5.3 | 9.3 | 9.3 | 9.5 | 8.2 |
| 60 | 2.7 | 7.0 | 8.2 | 11.8 | 11.6 | 14.4 | 12.1 |
| 120 | 2.9 | 7.8 | 9.7 | 13.0 | 13.5 | 15.5 | 13.6 |
| SE(±) | 0.44 | 0.40 | 0.45 | 0.54 | 0.79 | 0.63 | 0.94 |
| LSD(0.05) | NS | 1.11 | 1.25 | 1.49 | 2.10 | 1.75 | 2.59 |
| Spacing (cm) | | | | | | | |
| 40 | 2.8 | 7.3 | 8.3 | 8.2 | 12.3 | 13.7 | 12.4 |
| 30 | 3.0 | 6.4 | 7.9 | 11.4 | 11.4 | 13.3 | 11.2 |
| 20 | 2.8 | 5.7 | 7.0 | 10.4 | 10.8 | 12.4 | 10.3 |
| SE(±) | 0.44 | 0.40 | 0.45 | 0.54 | 0.79 | 0.63 | 0.95 |
| LSD(0.05) | NS | 1.11 | NS | NS | NS | NS | NS |
| Varicty | | | | | | | |
| B9462-1 | 2.7 | 5.9 | 6.9 | 11.5 | 10.9 | 13.0 | 10.9 |
| BR63-18 | 2.9 | 7.1 | 8.5 | 11.2 | 12.1 | 13.2 | 11.8 |
| SE(±) | 0.36 | 0.33 | 0.35 | 0.44 | 0.64 | 0.52 | 0.76 |
| LSD(0.05) | NS | 0.91 | 1.02 | NS | NS | NS | NS |

Table 3. The interaction between nitrogen and variety on the mean number of axillary branches of potato at four weeks after emergence, at Samaru in 1984.

| Treatment | Variety | |
|---|---|---|
| Nitrogen (kg/ha) | B9462-1 | PR63-18 |
| 0 | $5.1^{cd+}$ | $4.2^{d}$ |
| 60 | $5.9^{c}$ | $8.1^{ab}$ |
| 120 | $6.6^{bc}$ | $8.9^{a}$ |
| SE(±) | 0.57 | |

+ Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

4.1.3 Number of stems

In the first two weeks of sampling, nitrogen at 60 and 120 kg/ha being on par increased the number of stems significantly over 0 kg/ha level. From then onwards, there was a slight increase in number of stems per plant with each increase in the rate of nitrogen (Table 4).

So far as the formation of stems is concerned varying spacings failed to influence this character throughout the growing season except during four W.A.E. when closest spacing produced the least number of stem than either 30 or 40 cm spacings.

Table 4. Mean number of stems per plant of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 1.5 | 2.5 | 2.5 | 3.0 | 3.1 | 3.3 | 3.0 |
| 60 | 2.6 | 3.5 | 3.1 | 3.5 | 3.5 | 3.7 | 3.4 |
| 120 | 2.4 | 3.8 | 3.3 | 3.5 | 4.0 | 4.0 | 3.6 |
| SE(±) | 0.21 | 0.27 | 0.24 | 0.28 | 0.27 | 0.27 | 0.24 |
| LSD(0.05) | 0.50 | 0.74 | NS | NS | NS | NS | NS |
| Spacing(cm) | | | | | | | |
| 40 | 2.4 | 3.2 | 3.1 | 3.7 | 3.6 | 3.6 | 3.4 |
| 30 | 2.0 | 3.8 | 3.2 | 3.3 | 3.4 | 3.3 | 3.3 |
| 20 | 2.1 | 2.8 | 2.6 | 2.9 | 3.4 | 3.2 | 3.4 |
| SE(±) | 0.21 | 0.27 | 0.27 | 0.28 | 0.27 | 0.27 | 0.24 |
| LSD(0.05) | NS | 0.74 | NS | NS | NS | NS | NS |
| Variety | | | | | | | |
| B9462-1 | 1.8 | 3.0 | 3.1 | 3.1 | 3.5 | 3.4 | 3.3 |
| BR63-18 | 2.5 | 3.7 | 2.9 | 3.5 | 3.9 | 4.1 | 3.4 |
| SE(±) | 0.17 | 0.22 | 0.20 | 0.23 | 0.22 | 0.22 | 0.20 |
| LSD(0.05) | NS | NS | NS | NS | 0.62 | 0.61 | NS |

Both varieties were found to be similar except during the seventh and **eighth** W.A.E. when variety SR63-18 produced significantly more stems than variety B9462-1. An interesting observation concerning main and secondary branches was found during a critical study of these two varieties. The total number of stems per plant in variety B9462-1 was mainly composed of main stems while in variety SR63-18 they were composed of main and secondary stems.

4.1.4 Plant height

Table 5 reveals that plant height was not influenced by nitrogen in the early stage of growth but in the later stage it was influenced. There was no significant difference in the three levels of nitrogen up to five W.A.E., then up to eight W.A.E. the higher the level of nitrogen the more was the mean height of plants. At nine W.A.E. there was no significant difference between 60 and 120 kg N/ha but they were significantly superior to 0 kg/ha level of nitrogen.

Mean plant height though increased with increase in plant spacing, statistically, there was a non significant difference among the three spacings.

Variety B9462-1 produced taller plants at all stages of sampling than variety SR63-18. The differences in height were only significant in the later stages of growth i.e. from five to ten W.A.E.

Table 5: Mean plant height (cm) of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 16.43 | 25.36 | 31.5 | 37.1 | 43.7 | 53.2 | 67.9 |
| 60 | 16.52 | 27.40 | 33.2 | 42.2 | 49.4 | 59.0 | 74.1 |
| 120 | 16.88 | 28.3 | 33.3 | 47.1 | 55.1 | 65.4 | 78.4 |
| SE(±) | 0.83 | 0.88 | 0.72 | 1.10 | 0.95 | 1.58 | 1.63 |
| LSD(0.05) | NS | NS | NS | 3.26 | 2.63 | 4.37 | 4.53 |
| Spacing (cm) | | | | | | | |
| 40 | 16.27 | 28.7 | 33.3 | 43.9 | 49.7 | 60.4 | 75.1 |
| 30 | 16.78 | 26.2 | 32.2 | 40.9 | 49.1 | 59.9 | 73.3 |
| 20 | 16.78 | 26.2 | 32.5 | 41.6 | 49.5 | 57.2 | 72.1 |
| SE(±) | 0.83 | 0.88 | 0.72 | 1.18 | 0.95 | 1.58 | 1.63 |
| LSD(0.05) | NS | NS | NS | NS | NS | NS | NS |
| Variety | | | | | | | |
| B9462-1 | 17.00 | 28.0 | 34.9 | 46.3 | 55.4 | 66.2 | 80.3 |
| BR63-18 | 16.23 | 26.1 | 30.5 | 37.9 | 43.5 | 52.2 | 66.7 |
| SE(±) | 0.67 | 0.72 | 0.59 | 0.96 | 0.77 | 1.29 | 1.33 |
| LSD(0.05) | NS | NS | 1.63 | 2.66 | 2.15 | 3.57 | 3.70 |

There was no interaction effect among treatments.

4.1.5 Leaf dry weight

At the first and last sampling dates, nitrogen and plant spacing had no significant effect on the leaf dry weight per plant. From four W.A.E. to eight W.A.E. there was an increase in the leaf dry weight with increase in nitrogen application except at four and six W.A.E. when there was no significant difference between the two higher rates.

The significant effect of spacing could be seen from five W.A.E. (Table 6). The 40 cm spacing gave a significantly higher leaf dry weight per plant than 30 cm spacing which was at par with 20 cm spacing (i.e. at five, six and seven W.A.E.). At eight W.A.E. there was a significant increase with each increment in plant spacing. Early in the growing season, B9462-1 had a higher leaf dry weight per plant than BR63-18 up to eight W.A.E. when there was no significant difference between the two varieties. At the last sampling date however, BR63-18 gave a significantly higher leaf dry weight than variety B9462-1.

No interactions were observed among treatments.

Table 6. Mean leaf dry weight (g/plant) of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 4.5 | 8.1 | 8.1 | 12.7 | 17.8 | 26.6 | 21.7 |
| 60 | 5.0 | 7.3 | 10.7 | 16.2 | 24.6 | 42.2 | 24.3 |
| 120 | 5.3 | 8.0 | 12.1 | 17.5 | 27.7 | 48.8 | 24.1 |
| SE(±) | 0.28 | 0.27 | 0.42 | 0.58 | 0.63 | 0.79 | 1.77 |
| LSD(0.05) | NS | 0.76 | 1.17 | 1.32 | 1.75 | 2.19 | NS |
| Spacing (cm) | | | | | | | |
| 40 | 4.8 | 7.3 | 11.8 | 17.6 | 26.4 | 42.1 | 24.6 |
| 30 | 4.8 | 7.2 | 10.1 | 14.8 | 22.7 | 39.4 | 23.2 |
| 20 | 5.1 | 6.8 | 9.0 | 14.0 | 21.0 | 36.1 | 22.3 |
| SE(±) | 0.28 | 0.27 | 0.42 | 0.58 | 0.63 | 0.79 | 1.77 |
| LSD(0.05) | NS | NS | 1.17 | 1.32 | 1.75 | 2.19 | NS |
| Variety | | | | | | | |
| F9462-1 | 5.3 | 7.6 | 11.4 | 17.2 | 24.7 | 39.7 | 21.1 |
| BR63-18 | 4.6 | 6.6 | 9.2 | 13.8 | 22.0 | 38.7 | 25.7 |
| SE(±) | 0.23 | 0.22 | 0.44 | 0.47 | 0.51 | 0.64 | 1.44 |
| LSD(0.05) | 0.63 | 0.62 | 0.95 | 1.31 | 1.43 | NS | NS |

4.1.6 Stem dry weight

There was marked effect of nitrogen on stem dry weight. Throughout the sampling period except in the third W.A.E. there was significant effect of nitrogen on the stem dry weight which increased significantly with each increment in the rate of nitrogen except at nine W.A.E. when 60kg N and 120kg N/ha had a similar effect (Table 7).

The increase in stem dry weight per square meter with each reduction in spacing was significant. This implies that the 20cm spacing had the highest stem dry weights per unit area than the other spacings.

During the early part of the growing period variety B9462-1 had higher stem dry weights than variety BR63-18 while in the later part of the season, the reverse was true.

There was a significant nitrogen x spacing interaction effect on stem dry weight only at six and eight W.A.E. (Table 8). 0 kg N/ha produced least stem dry weight with all the spacings at six and eight W.A.E. 60 and 120kgN/ha levels being at par produced more stem dry weight at 40 and 30 cm spacings in the sixth W.A.E. whereas at 30 and 20 cm spacings at eight W.A.E., respectively. The higher the level of nitrogen the higher was the stem dry weight at 20 cm spacing at six W.A.E. and at 40 cm spacing at eight W.A.E., respectively.

Table 7. Mean stem dry weight ($g/m^2$) of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 6.0 | 8.1 | 12.4 | 20.7 | 33.5 | 35.4 | 35.5 |
| 60 | 6.3 | 10.4 | 17.9 | 31.5 | 53.2 | 71.4 | 62.3 |
| 120 | 6.6 | 11.8 | 20.3 | 38.4 | 62.0 | 78.9 | 75.0 |
| SE(±) | 0.44 | 0.42 | 0.55 | 0.97 | 1.60 | 1.35 | 4.67 |
| LSD(0.05) | NS | 1.15 | 1.52 | 2.68 | 4.44 | 3.74 | 12.93 |
| Spacing | | | | | | | |
| 40 | 4.2 | 7.1 | 12.7 | 22.5 | 37.6 | 47.6 | 39.1 |
| 30 | 5.8 | 9.8 | 15.5 | 26.7 | 44.5 | 61.7 | 58.1 |
| 20 | 8.9 | 13.3 | 22.2 | 41.5 | 66.5 | 76.3 | 75.6 |
| SE(±) | 0.44 | 0.42 | 0.55 | 0.97 | 1.60 | 1.35 | 4.67 |
| LSD(0.05) | 1.23 | 1.15 | 1.52 | 2.68 | 4.44 | 3.74 | 12.93 |
| Variety | | | | | | | |
| B9462-1 | 6.4 | 10.8 | 17.5 | 32.7 | 58.1 | 60.0 | 52.7 |
| BR63-18 | 6.2 | 9.4 | 16.1 | 27.8 | 41.0 | 63.7 | 62.6 |
| SE(±) | 0.36 | 0.34 | 0.45 | 0.79 | 1.31 | 1.10 | 3.81 |
| LSD(0.05) | NS | 0.94 | 1.24 | 2.19 | 3.62 | 3.05 | NS |

The nitrogen x variety interaction was significant only during seven and eight W.A.E. (Table 9). In seven W.A.E. performances of both the vatieties with different levels of nitrogen were the same, i.e. the higher the level of nitrogen, the higher was the stem dry weight. Similar trend was found only with variety BR63-18 during eight W.A.E. During that period in variety B9462-1, the two higher levels of nitrogen being statistically similar were superior to 0 kg/ha level.

Table 8. The interaction of nitrogen and spacing on stem dry weight ($g/m^2$) of potato at six and eight weeks after emergence at Samaru in 1984.

| Nitrogen | Spacing (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 6 weeks | | | 8 weeks | | |
| (kg/ha) | 40 | 30 | 20 | 40 | 30 | 20 |
| 0 | $16.1^{g+}$ | $19.1^{f}$ | $26.9^{de}$ | $24.9^{e}$ | $34.7^{d}$ | $46.4^{c}$ |
| 60 | $23.3^{ef}$ | $28.7^{cd}$ | $42.6^{b}$ | $52.5^{c}$ | $72.6^{b}$ | $89.2^{a}$ |
| 120 | $28.1^{cde}$ | $32.4^{c}$ | $54.8^{a}$ | $65.5^{b}$ | $77.9^{b}$ | $93.2^{a}$ |
| SE(±) | | 1.67 | | | 2.33 | |

+ Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

Table 9. The interaction of nitrogen and variety on stem dry weight ($g/m^2$) of potato at seven and eight weeks after emergence at Samaru in 1984.

| Nitrogen | 7 weeks | | 8 weeks | |
|---|---|---|---|---|
| (kg/ha) | B9462-1 | BR63-18 | B9462-1 | BR63-18 |
| 0 | $36.1^{de+}$ | $30.9^{e}$ | $38.2^{d}$ | $32.5^{d}$ |
| 60 | $65.1^{b}$ | $41.3^{d}$ | $68.3^{c}$ | $74.6^{b}$ |
| 120 | $73.2^{a}$ | $50.7^{c}$ | $73.6^{bc}$ | $84.1^{a}$ |
| SE(±) | 2.25 | | 1.91 | |

+ Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

4.1.7 Tuber dry weight

Early in the growing season i.e. during six and seven W.A.E. the 0 and 60 kgN/ha levels being at par produced significantly higher tuber dry weight than 120kgN/ha, whereas later in the season 60 and 120 kgN/ha levels were similar but statistically superior to no nitrogen level (Table 10).

Spacing treatments did not have any significant effect on tuber dry matter yield till seven W.A.E. From eight W.A.E, the widest spacing (40cm) produced significantly more tuber dry weight over the closest spacing (20cm). Medium spacing was at par with the other two spacings.

Table 10. Mean tuber dry weight (g/plant) of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | |
|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 |
| Nitrogen (kg/ha) | | | | | |
| 0 | 6.5 | 13.1 | 17.4 | 25.1 | 27.3 |
| 60 | 6.0 | 13.6 | 23.0 | 32.6 | 41.2 |
| 120 | 3.6 | 10.7 | 25.3 | 33.7 | 42.6 |
| SE(±) | 0.46 | 0.83 | 0.90 | 0.92 | 0.85 |
| LSD(0.05) | 1.26 | 2.31 | 2.50 | 2.54 | 2.35 |
| Spacing (cm) | | | | | |
| 40 | 5.7 | 13.0 | 20.4 | 32.4 | 39.0 |
| 30 | 5.9 | 12.5 | 18.8 | 28.2 | 35.3 |
| 20 | 4.6 | 10.8 | 16.6 | 23.8 | 37.8 |
| SE(±) | 0.46 | 0.83 | 0.90 | 0.92 | 0.85 |
| LSD(0.05) | NS | NS | 2.50 | 2.54 | 2.35 |
| Variety | | | | | |
| B9462-1 | 0.5 | 18.8 | 27.6 | 39.7 | 49.2 |
| BR63-18 | 2.3 | 5.5 | 9.5 | 16.7 | 24.2 |
| SE(±) | 0.37 | 0.68 | 0.74 | 0.75 | 0.69 |
| LSD(0.05) | 1.03 | 1.88 | 2.04 | 2.07 | 1.92 |

Variety B9162-1 produced significantly more tuber dry matter than variety ER63-18 throughout the sampling period.

At nine and ten W.A.E. only, there was a nitrogen x variety interaction effect on tuber dry weight (Table 11). At nine W.A.E., variety ER63-18 produced similar tuber dry weight, at all nitrogen levels 60 and 120kg N/ha were statistically at par but significantly superior to 0 kg N/ha level for variety B9162-1 alone at nine W.A.E and for both varieties at ten W.A.E.

Another interaction effect observed at nine and ten W.A.E on tuber dry weight was between nitrogen and spacing (Table 12). At nine W.A.E. 0 kg/ha nitrogen level produced similar tuber dry weights at all spacings. With 60 kgN/ha, the least tuber dry weight was obtained with the closest spacing. There was no difference between 30 and 40cm spacing. With 120 kgN/ha, 40 cm spacing produced more dry weight than 20 and 30cm spacings. At ten W.A.E. the performance of 0 kg level of nitrogen at different spacings was the same as at nine W.A.E. There was no significant difference between 60 and 120 kg N/ha at 20 and 30cm spacings. Both these levels being at par produced more dry weight at 40cm spacing than the other two spacings.

Table 11. The interaction of nitrogen and variety on tuber dry weight (g/plant) of potato at nine and ten weeks after emergence at Samaru in 1984.

| Nitrogen ( | 9 weeks | | 10 weeks | |
|---|---|---|---|---|
| (kg/ha) | B9462-1 | BR63-18 | B9462-1 | BR63-18 |
| 0 | 35.1$^{b+}$ | 15.1$^{c}$ | 35.4$^{b}$ | 21.2$^{d}$ |
| 60 | 47.39 | 17.9$^{c}$ | 57.2$^{a}$ | 25.2$^{c}$ |
| 120 | 46.5$^{a}$ | 17.0$^{c}$ | 58.9$^{a}$ | 26.3$^{c}$ |
| SE(±) | 1.30 | | 1.20 | |

+ Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

Table 12. The interaction of nitrogen and spacing on tuber dry weight (g/plant) of potato at 9 and 10 weeks after emergence. at Samaru in 1984.

| Nitrogen | 9 weeks | | | 10 weeks | | |
|---|---|---|---|---|---|---|
| (kg/ha) | 40cm | 30cm | 20cm | 40cm | 30cm | 20cm |
| 0 | 27.0$^{bc+}$ | 23.6$^{c}$ | 24.8$^{c}$ | 29.7$^{c}$ | 15.1$^{d}$ | 19.7$^{d}$ |
| 60 | 39.5$^{a}$ | 35.7$^{a}$ | 22.7$^{c}$ | 42.8$^{ab}$ | 42.0$^{ab}$ | 38.8$^{b}$ |
| 120 | 30.8$^{b}$ | 25.3$^{c}$ | 24.1$^{c}$ | 44.6$^{a}$ | 41.2$^{ab}$ | 39.1$^{b}$ |
| SE ± | | 1.59 | | | 1.47 | |

+ Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

4.1.8 Total dry weight

At four and five W.A.E., there was a significant increase in total dry weight per plant with increase in nitrogen level. Thereafter, the total dry weights per plant were statistically similar for both 60 and 120 kg N/ha, but were both significantly higher than that of the plots with no nitrogen (Table 13). The total dry weight per plant increased with time until eight W.A.F., after which it started decreasing.

There was no significant effect of spacing on total dry weight per plant up to four W.A.E.From five to eight W.A.E.,the total dry weight per plant reduced significancly with each reduction in spacing between plants. At nine W.A.E. there was no difference between 20 and 30cm spacings, nor was there any differences between 30 and 40cm spacings.

At three W.A.E., there was no difference between the two varieties, but from four W.A.E to nine W.A.E variety B9462-1 produced simnificantly higher total dry weights per plant than variety BR63-18. It was observed that from five W.A.E. to harvest, variety BR63-18 produced a lot of flowers and berries which contributed considerably to the total dry weights of this variety. With variety B9462-1, very few plants produced flowers but no fruits were formed. In the later part of the growing period, the tuber dry weight of variety B9462-1

Table 13. Total dry weight (g/plant) of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | | |
| 0 | 6.7 | 8.9 | 12.3 | 25.6 | 40.2 | 54.6 | 59.2 |
| 60 | 7.2 | 10.9 | 16.1 | 31.8 | 52.2 | 83.2 | 74.6 |
| 120 | 7.6 | 12.1 | 18.1 | 32.5 | 53.8 | 85.0 | 73.7 |
| SE(±) | 0.35 | 0.32 | 0.42 | 0.81 | 1.13 | 1.35 | 2.52 |
| LSD(0.05) | NS | 0.99 | 1.17 | 2.25 | 3.13 | 3.74 | 7.00 |
| Spacing (cm) | | | | | | | |
| 40 | 7.1 | 10.9 | 17.3 | 32.0 | 53.5 | 80.7 | 74.0 |
| 30 | 7.1 | 10.7 | 15.3 | 29.3 | 47.9 | 74.1 | 10.1 |
| 20 | 7.3 | 10.3 | 13.9 | 26.6 | 44.7 | 67.9 | 63.4 |
| SE(±) | 0.35 | 0.32 | 0.42 | 0.81 | 1.13 | 1.35 | 2.52 |
| LSD(0.05) | NS | NS | 1.17 | 2.25 | 3.13 | 3.74 | 7.00 |
| Variety | | | | | | | |
| P9462-1 | 7.5 | 11.3 | 16.8 | 34.3 | 58.5 | 83.7 | 74.6 |
| ER63-18 | 6.9 | 9.9 | 14.1 | 25.6 | 38.9 | 64.8 | 63.8 |
| SE(±) | 0.28 | 0.26 | 0.34 | 0.66 | 0.92 | 1.10 | 2.06 |
| LSD(0.05) | NS | 0.73 | 0.95 | 1.83 | 2.56 | 3.05 | 5.71 |

added more to the total dry weight per plant than any of the other components as compared to variety BR63-18 which composed more of haulm dry weight.

Significant interactions between nitrogen x variety (Table 14) and spacing x variety (Table 15) were observed at nine and five WAE respectively. Variety B9462-1 significantly produced more total dry matter than variety BR63-18 with 0 and 60kgN/ha levels and also at wider spacings of 30 and 40cm. The two varieties did not differ among themselves either with 120kg nitrogen level or at the closest spacing of 20cm.

Table 14: The interaction of nitrogen and variety on total dry weight (g/plant) of potato at nine weeks after emergence at Samaru in 1984.

| Nitrogen (kg/ha) | B9462-1 | BR63-18 |
|---|---|---|
| 0 | $65.7^{b*}$ | $52.7^{c}$ |
| 60 | $84.7^{a}$ | $64.4^{b}$ |
| 120 | $73.2^{b}$ | $74.1^{b}$ |
| SE(±) | 3.57 | |

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

Table 15. The interaction of spacing and variety on the total dry weight (g/plant) of potato at five weeks after emergence at Samaru in 1984.

| Spacing (cm) | B9h62-1 | BR63-18 |
|---|---|---|
| 40 | 19.[illegible]$^{a+}$ | 15.0$^{b}$ |
| 30 | 1[illegible].3$^{b}$ | 1[illegible].2$^{c}$ |
| 20 | 1[illegible].6$^{bc}$ | 13.1$^{c}$ |
| SE(±) | 0.60 | |

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

4.1.9 Leaf area index (LAI)

There was a rapid increase in the growth of leaves between the fifth and seventh WAE, and LAI increased accordingly reaching its peak value (3.4) at seven WAE after which it started declining. Nitrogen fertilization had a marked effect on LAI during the first three sampling dates. At three and five WAE 60 and 120kg N/ha levels being at par were significantly higher than 0 kg N/ha level. At seven WAE, LAI increased significantly with each increase in nitrogen level. By nine WAE, there was no longer any marked effect of nitrogen on LAI (Table 16).

At the first, second and fourth sampling dates (3, 7 and 9 WAE), there was a decrease in LAI with each increase in spacing. The 30 and 40 cm spacings

Table 16. Leaf area index of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | |
|---|---|---|---|---|
| | 3 | 5 | 7 | 9 |
| Nitrogen (kg/ha) | | | | |
| 0 | 0.5 | 0.8 | 2.1 | 2.0 |
| 60 | 0.6 | 1.2 | 3.0 | 2.5 |
| 120 | 0.7 | 1.2 | 3.4 | 2.8 |
| SE(±) | 0.04 | 0.07 | 0.14 | 0.22 |
| LSD(0.05) | 0.10 | 0.19 | 0.38 | NS |
| Spacing (cm) | | | | |
| 40 | 0.4 | 0.9 | 2.4 | 1.9 |
| 30 | 0.6 | 0.9 | 2.8 | 2.5 |
| 20 | 0.9 | 1.3 | 3.4 | 3.0 |
| SE(±) | 0.04 | 0.07 | 0.14 | 0.22 |
| LSD(0.05) | 0.10 | 0.19 | 0.38 | 0.44 |
| Variety | | | | |
| B9462-1 | 0.7 | 1.1 | 3.1 | 2.5 |
| BR63-18 | 0.6 | 1.0 | 2.6 | 2.4 |
| SE(±) | 0.03 | 0.06 | 0.12 | 0.18 |
| LSD(0.05) | NS | 0.15 | 0.31 | NS |

produced similar LAI values which were significantly lower than 20cm spacing at five WAE.

There was no significant difference between both varieties at three and nine WAE, but at five and seven WAE variety B9462-1 produced significantly higher LAI values than variety BR63-18.

There were no significant interaction effects on LAI among treatments.

4.1.10 Net assimilation rate (NAR)

NAR was highest at three WAE after which there was a drop, increasing again at seven WAE before a final drop. Nitrogen did not produce any significant effect on NAR at three WAE. At five WAE 120kg N/ha level was significantly superior to 0 and 60 kg N/ha levels which were both similar (Table 17). Seven WAE 60kg N/ha produced NAR similar to that of both 0 and 120kg N/ha levels, but 0 kgN/ha was significantly superior to 120kg N/ha. At the last sampling date, 0kg N/ha level gave significantly higher results than 60 and 120kgN/ha levels which were both at par.

Throughout the sampling period, there was a significant increase in NAR with each increase in plant spacing.

The only significant difference between the two varieties was found at seven WAE when variety B9462-1

Table 17. Net assimilation rate of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | |
|---|---|---|---|---|
| | 3 | 5 | 7 | 9 |
| Nitrogen (kg/ha) | | | | |
| 0 | 0.9 | 0.6 | 1.1 | 1.0 |
| 60 | 0.9 | 0.6 | 0.9 | 0.7 |
| 120 | 0.9 | 0.7 | 0.8 | 0.6 |
| SE(±) | 0.03 | 0.04 | 0.07 | 0.07 |
| ISD(0.05) | NS | 0.11 | 0.20 | 0.14 |
| Spacing (cm) | | | | |
| 40 | 1.2 | 0.8 | 1.3 | 1.0 |
| 30 | 1.0 | 0.6 | 1.0 | 0.8 |
| 20 | 0.6 | 0.4 | 0.7 | 0.4 |
| SE(±) | 0.03 | 0.04 | 0.07 | 0.07 |
| LSD(0.05) | 0.08 | 0.11 | 0.20 | 0.14 |
| Variety | | | | |
| B9462-1 | 0.9 | 0.7 | 1.1 | 0.7 |
| BR63-18 | 0.9 | 0.6 | 0.8 | 0.8 |
| SE(±) | 0.02 | 0.03 | 0.06 | 0.05 |
| LSD (0.05) | NS | NS | 0.16 | NS |

produced significantly higher NAR than variety BR63-18.

At nine WAE, there was a significant interaction effect on NAR between nitrogen and spacing (Table 18). At 0 kgN/ha, 40 cm spacing produced significantly the highest NAR, while the 60 and 120 kg N/ha levels were statistically at par at this spacing. With 0 and 60kg N/ha 30cm spacing produced NAR values which were statistically similar, but both higher than the 120kg N/ha level. All levels of nitrogen were observed to have similar results at 20 cm spacing.

Table 18. The interaction of nitrogen and spacing on the net assimilation rate of potato at nine weeks after emergence at Samaru in 1984.

| | Spacing (cm) | | |
|---|---|---|---|
| Nitrogen (kg/ha) | 40 | 30 | 20 |
| 0 | $1.4^{a*}$ | $1.0^{b}$ | $0.5^{d}$ |
| 60 | $0.9^{bc}$ | $1.0^{b}$ | $0.3^{d}$ |
| 120 | $0.8^{c}$ | $0.5^{d}$ | $0.4^{d}$ |
| SE(±) | 0.09 | | |

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance.

## 4.2 Yield and Yield Related Characters

### 4.2.1 Total yield

Table 19 reveals that nitrogen has influenced the yielding capacity of potato. Nitrogen level of 60kg/ha increased the tuber yield by 50% over no nitrogen level. The higher level of nitrogen (i.e. 120kg/ha) was statistically similar to 60kg N/ha level.

The closer the spacing, the higher was the tuber yield. 20cm spacing produced highest yield (8.8t/ha) followed by 30cm spacing (8.0t/ha). These two spacings being at par produced significantly more yield than 40cm spacing.

Variety B9462-1 yielded significantly more than variety BR63-18.

There was no significant interaction effect among treatments.

### 4.2.2 Total number of tubers

After tuber initiation, the number of tubers per plant reached a peak at seven WAE, after which it started reducing. The effect of nitrogen on the number of tubers per plant was only observed during the later part of the sampling period. At eight WAE, 60 kgN/ha level produced similar results to both 0 and 120kg N/ha levels, but 120kgN/ha had significantly more tubers than 0 kgN/ha. At nine WAE, the two higher

Table 19. Total yield and total number of tubers/$m^2$ of potato at harvest as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Total yield (t/ha) | Total number of tubers/$m^2$ |
|---|---|---|
| Nitrogen (kg/ha) | | |
| 0 | 5.7 | 33.4 |
| 60 | 8.5 | 40.8 |
| 120 | 8.7 | 42.3 |
| SE(±) | 0.30 | 1.14 |
| LSD(0.05) | 0.82 | 3.16 |
| Spacing (cm) | | |
| 40 | 6.0 | 27.0 |
| 30 | 8.0 | 36.7 |
| 20 | 8.8 | 52.8 |
| SE(±) | 0.30 | 1.14 |
| LSD(0.05) | 0.82 | 3.16 |
| Variety | | |
| B9462-1 | 10.2 | 31.5 |
| BR63-18 | 5.0 | 45.1 |
| SE(±) | 0.24 | 0.93 |
| LSD(0.05) | 0.67 | 2.58 |

levels of nitrogen were at par but significantly higher than 0 kg N/ha level (Table 20). At harvest nitrogenn levels also influenced the total number of tubers. Nitrogen at 60kg/ha significantly increased the number of tubers over no nitrogen. No significant differences were found between 60 and 120kg N/ha (Table 19).

Only at five, nine WAE and at harvest were there any significant effects of spacing on the number of tubers produced. At five WAE, the closest spacing had the least number of tubers per plant while the widest spacing had the highest number of tubers. The medium spacing (30cm) had statistically similar results with the other two spacings. At nine WAE 40cm spacing produced significantly more tubers than 30 and 20cm spacings which were both at par. At harvest, the total number of tubers/$m^2$ increased with closer plant spacing. The three spacings of 20, 30 and 40 cm produced 52.8, 36.7 and 27.0 tubers/$m^2$, respectively.

Except at the first sampling date that variety B9462-1 produced significantly more tubers than variety BR63-18, during the later part of the sampling period (seven to nine WAE) variety BR63-18 produced significantly more tubers per plant than variety B9462-1. At six WAE, there was no significant difference between the varieties. At harvest, variety BR63-18 had significantly more tubers per plant than the other variety (Table 19).

Table 20. Number of tubers per plant of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | |
| 0 | 2.8 | 6.1 | 8.7 | 7.5 | 5.9 |
| 60 | 2.6 | 7.0 | 9.8 | 8.4 | 8.2 |
| 120 | 2.8 | 7.2 | 10.8 | 9.9 | 9.2 |
| SE(±) | 0.23 | 0.59 | 0.63 | 0.66 | 0.47 |
| LSD(0.05) | NS | NS | NS | 1.82 | 1.30 |
| Spacing (cm) | | | | | |
| 40 | 3.3 | 7.9 | 10.3 | 9.4 | 8.9 |
| 30 | 2.8 | 6.5 | 9.8 | 8.3 | 7.0 |
| 20 | 2.2 | 6.0 | 9.1 | 8.1 | 6.9 |
| SE(±) | 0.23 | 0.59 | 0.63 | 0.66 | 0.47 |
| LSD(0.05) | 0.63 | NS | NS | NS | 1.30 |
| Variety | | | | | |
| B9462-1 | 3.6 | 7.1 | 8.1 | 7.0 | 6.8 |
| BR63-18 | 1.8 | 6.5 | 11.3 | 9.9 | 8.4 |
| SE(±) | 0.18 | 0.48 | 0.51 | 0.54 | 0.38 |
| LSD(0.05) | 0.51 | NS | 1.42 | 1.49 | 1.06 |

There was a significant interaction effect between spacing and variety at harvest (Table 21). At each spacing, variety BR63-18 produced significantly higher number of tubers/$m^2$ than variety B9462-1.

Table 21. The interaction of spacing and variety on the total number of tubers/$m^2$ of potato at harvest at Samaru in 1981.

| | Spacing (cm) | | |
|---|---|---|---|
| | 40 | 30 | 20 |
| B9462-1 | 23.3$^{d+}$ | 29.5$^{c}$ | 41.7$^{b}$ |
| BR63-18 | 30.3$^{c}$ | 43.9$^{b}$ | 63.8$^{a}$ |
| SE(±) | | 1.61 | |

4.2.3 Number of stolons

The number of stolons per plant was affected by nitrogen application throughout the sampling period. At four WAE, 0 and 60kg N/ha were statistically similar, but both significantly less than 120 kgN/ha level. From five to nine WAE, the 60 and 120 kgN/ha levels were at par but significantly higher than the no nitrogen level (Table 22).

A significant effect of spacing on the number of stolons per plant was only observed during six and seven WAE. During this period, the 30 cm spacing was similar statistically to both 20 and 40cm spacings, but the 40cm spacing produced significantly more stolons than 20cm spacing.

Table 22. Number of stolons per plant of potato at different sampling stages as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Weeks After Emergence | | | | | |
|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 |
| Nitrogen (kg/ha) | | | | | | |
| 0 | 2.9 | 4.0 | 8.3 | 12.9 | 12.2 | 12.2 |
| 60 | 3.9 | 6.6 | 9.8 | 16.2 | 15.5 | 15.6 |
| 120 | 5.1 | 7.2 | 10.5 | 17.6 | 18.0 | 18.1 |
| SE(±) | 0.46 | 0.45 | 0.52 | 0.93 | 0.96 | 0.98 |
| LSD(0.05) | 1.27 | 1.26 | 1.45 | 2.57 | 2.65 | 2.68 |
| Spacing (cm) | | | | | | |
| 40 | 4.7 | 6.3 | 10.4 | 17.3 | 16.6 | 16.7 |
| 30 | 3.7 | 5.8 | 9.7 | 15.5 | 14.8 | 14.7 |
| 20 | 3.5 | 5.7 | 8.5 | 14.9 | 14.3 | 14.3 |
| SE(±) | 0.46 | 0.45 | 0.52 | 0.93 | 0.96 | 0.98 |
| LSD(0.05) | NS | NS | 1.45 | 2.57 | NS | NS |
| Variety | | | | | | |
| B9462-1 | 4.9 | 7.7 | 10.1 | 14.4 | 13.8 | 13.9 |
| BR63-18 | 3.0 | 4.2 | 9.0 | 16.8 | 16.7 | 16.9 |
| SE(±) | 0.37 | 0.37 | 0.43 | 0.76 | 0.78 | 0.80 |
| LSD(0.05) | 1.03 | 1.03 | NS | 2.10 | 2.17 | 2.36 |

Significant varietal differences in the number of stolons per plant were observed throughout the sampling period except at six W/E when this difference was not significant. In the early part of the sampling period, variety B9462-1 had significantly more stolons than variety BR63-18 while later (seven to nine W/E), variety BR63-18 had more stolons than variety B9462-1.

No interaction effects on this character was observed among the various treatments throught the sampling period.

## 4.3 Tuber Quality

### 4.3.1 Dry matter (DM), starch and crude protein (CP) contents

Although a slight increase was found in the DM% and starch % with increasing levels of nitrogen and closeness of spacing, these differences were non-significant (Table 23). Only CP% was significantly influenced by nitrogen levels and spacings; the higher the rate of nitrogen, the higher was the CP% similarly, the wider the spacing, the more was the CP%. The CP% with 0, 60, 120kg N/ha and 40, 30 and 20cm spacings were 2.01, 2.13, 2.53 and 2.33, 2.21, 2.12, respectively.

Variety BR63-18 had a significantly higher CP content (2.29%) than variety B9462-1 (2.16%).

No significant interaction effects were observed among nitrogen fertilization, spacing and variety.

Table 23. Per cent dry matter (DM), crude proten (CF) and starch of potato tubers as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | DM(%) | CF(%) | starch(%) |
|---|---|---|---|
| Nitrogen (kg) | | | |
| 0 | 16.53 | 2.01 | 15.5 |
| 60 | 17.17 | 2.13 | 15.7 |
| 120 | 18.10 | 2.53 | 16.2 |
| SE(±) | 0.51 | 0.03 | 0.25 |
| LSD(0.05) | NS | 0.08 | NS |
| Spacing (cm) | | | |
| 40 | 16.94 | 2.33 | 15.4 |
| 30 | 17.30 | 2.21 | 15.7 |
| 20 | 17.60 | 2.12 | 16.2 |
| SE(±) | 0.51 | 0.03 | 0.25 |
| LSD(0.05) | NS | 0.08 | NS |
| Variety | | | |
| B9462-1 | 16.87 | 2.16 | 15.5 |
| BR63-18 | 17.66 | 2.29 | 16.0 |
| SE(±) | 0.41 | 0.02 | 0.20 |
| LSD(0.05) | NS | 0.07 | NS |

4.3.2 Size of tubers

Nitrogen fertilization had a marked effect on the yield of tubers of >40mm size. There was no significant difference in the yield of this grade of tubers when 60kg N/ha or 120kg N/ha was applied, but yields from these treatments were significantly higher than when no nitrogen was applied.

20 and 30cm spacings had no remarkable difference in the yield of tubers of >40mm size but yields with 20cm spacing were significantly higher than that of 40cm spacing.

Variety BR63-18 had significantly less yield of tubers of this grade than variety B9462-1 (Table 24). Interaction effects were non-significant.

With nitrogen levels, a similar trend was observed with the yield of tubers of <40mm size (Table 24). There was an increase in yield of tubers of <40mm with increase in nitrogen level from 0 to 60 kg/ha. There was no significant difference when 60 or 120kgN/ha was used.

The yield of tubers of <40mm size from spacings of 30cm and 20cm were similar but were both significantly higher than the yield from 40cm spacing.

Variety B9462-1 gave significantly higher yields of tubers of <40mm size than variety BR63-18, which however had more number of tubers of this grade than the other variety.

There were no significant interaction effects.

Table 24. Yield of potato tubers of different grades (i.e. >40mm and <40mm) at harvest as influenced by nitrogen, spacing and variety at Samaru in 1984.

| Treatment | Tubers >40mm (t/ha) | Tubers <40mm (t/ha) |
|---|---|---|
| Nitrogen (kg/ha) | | |
| 0 | 3.00 | 2.74 |
| 60 | 3.93 | 4.56 |
| 120 | 4.14 | 4.48 |
| SE(±) | 0.22 | 0.21 |
| LSD(0.05) | 0.61 | 0.59 |
| Spacing (cm) | | |
| 40 | 3.20 | 2.80 |
| 30 | 3.78 | 4.23 |
| 20 | 4.08 | 4.75 |
| SE(±) | 0.22 | 0.21 |
| LSD(0.05) | 0.61 | 0.59 |
| Variety | | |
| B9462-1 | 5.71 | 4.50 |
| BR63-18 | 1.66 | 3.36 |
| SE(±) | 0.18 | 0.7 |
| LSD(0.05) | 0.50 | 0.48 |

Chapter 5

Dig **CON**

## 5• '1 Effect of Nitr on Plant ''Growth Yiln and **Qua** Tubers

The effect of nitrogen could be seen very clearly on the colour of leaves in the field. Leaves from non-nitrogen plots were pale green in appearance while those from plots with upto 120': /ha were dark green in colour indicating the occurence OJ high photivsynthetic activity. The pale coloured leave; Lso senes«ad earlier than the dark coloured leaves,confirming the **fact** that nitrogen helps to prolong the productive period of leaves. The number of leaves kept asing throughout the growing-season except at nine I ten there was a drop in the total number of leaves p Lant. Th< leer was due to the incidence of a dJ i caused by Phytophthora s (Late blight). rot (Erwinia phytophthora Appel) and lea ot (Al ern&ria solani) ore other diseases which were found in the field though of minor importance as they caused very little damage to the leaves. In plants where the disease attacked tl i >w< r art of the stem many more leaves were lost than when individual leaves were afl . The loss of leaves reduced the number and dry matter of leaves thus adversely affecting the photosynthetic capacity of the plant. Before the peak period of leaf lo$_s$s, variety B9I+62-1

was ready for harvest so it probably had little or no effect on the total yield of tubers. With variety BR63-18 only plots with no nitrogen were ready for harvest. Upto eight WAE the plots with variety BR63-18 having 120kgN/ha level were still dark green in colour and flowering showing that a lot of photosynthetic activity was still going on in the plants. The occurence of the disease (late blight) contributed very much to the low yields of this variety. This is because full ground cover by leaves of this varietyoccurred late in the growing season and when leaves were at their peak of production of assimilates, they were destroyed. The potential growth period and potential yield were thus reduced. On the other hand, variety BR62-1 which had an earlier coverage of the ground was able to utilize better the available growth period before the outbreak of the disease. This supports the view of Allen and Scott(1980) who stated that diseases especially potato blight is a very important factor in determining the persistence of the canopy.

Nitrogen fertilization had a significant effect on number of leaves per plant from early stages of growth. The number of leaves increased with increase in nitrogen level and leaves from plots with 120kgN/ha persisted longer than leaves from plots with 60kgN/ha which further out lived those with no nitrogen. This agrees with the work of Dyson and Watson (1971) who observed that high rates of nitrogen (200-250kgN/ha) can prolong foliage

growth by upto six weeks in a wet season as compared to crops given no nitrogen. Prolonging foliage growth can be advantageous due to the fact that a long period is provided for the production of assimilates. On the other hand this can have an adverse effect for a wet season crop as was the case in this experiment. Late in the season, occurence of a disease had the implication that the crop had wasted assimilation products on haulm growth which has not been utilized for increasing tuber yield towards the end of the growing season. Obviously if a late maturing variety stays photosynthetically active in the field long enough with favourable conditions for growth it tends to out yield an early maturing variety because it has a longer period available to produce assimilates which get stored in the tubers. With a long cyclic crop, there is a more extensive haulm growth, tuber growth begins later and maturity sets in later.

The number of stems increased upto the fourth WAE after which time the number remained relatively constant or increased only slightly. The auxillary branches however kept increasing for most of the season being more with variety BR63-18. Considering the number of branches per plant, variety BR63-18 is expected to have produced more leaves than variety B9462-1 but this was not the case. The longer stems of variety B9462-1 might have compensated for the lower number of branches. Also the leaves of this variety were larger than those of

variety BR63-18. These characteristics made the former variety to attain a good coverage of the soil earlier than the latter.

There was a significant incremental effect of nitrogen on the number of stems per plant up to four WAE. After this time the increase was very slight until the occurance of the disease after which there was a decrease. The number of axillary branches however increased significantly with increase in nitrogen fertilization from four WAE till the end of the season. At four WAE, the increase in the number of axillary branches must have been due to the combined effect of nitrogen and variety. Towards the end of the season, variety BR63-18 appeared about as big as variety B9462-1, due to its ability to produce more branches.

For much of the growing season the LAI ranged between 1 and 3.4; variety B9462-1 generally having a higher value than variety BR63-18 throughout the season. Nitrogen had an obvious effect on the LAI, which increased with increase in nitrogen level. At seven WAE, when the LAI was maximum, 120kgN/ha level produced the highest value of 3.4 while 0kgN/ha level had the lowest value of 2.1. LAI values increased with increase in haulm growth and declined with aging of the leaves and loss of leaves due to disease. The peak period of LAI coincided with the peak of tuber bulking indicating that a lot of assimilates produced as a result of the large

leaf area were being stored in the tubers. The importence of nitrogen fertilization was to maintain a good leaf area for the production of assimilates needed for haulm and tuber growth.

Leaf and stem growth were increased by nitrogen fertilization from an early stage of growth as was reported by Dyson and Watson, (1971). In this order the dry weights of these components too were increased and kept increasing uptill eight WAE before a drop. The interaction effects later in the growing season between nitrogen x spacing and nitrogen x variety show that the factors did not affect stem, tuber and total dry weights in isolation. The closer the spacing between plants, the more was the effect of nitrogen on increasing the dry weights of these parameters. As regards nitrogen x variety, interactions when these were significant (seven and eight WAE), the two varieties behaved similarly to 0 kgN/ha, but at each higher nitrogen level, variety B9462-1 yielded more stem dry matter than variety BR63-18. Later however, the reverse was true, variety BR63-18 yielding more. For the tubers, at all nitrogen levels, variety B9462-1 produced a higher dry weight than the other variety. These all show that potato varieties behave differently to nitrogen fertilization and an interaction between variety and treatment applied could be observed at certain stages of growth. The decrease in haulm dry weight which is a function of number of

stems and number and size of leaves borne on these stems, is due partly to the aging of the leaves and partly to the occurence of disease in the later part of the growing season. Early in the growing season the haulm contributed more to the total dry weight until after tuber initiation when tubers formed a significant part of the total dry weight per plant.

In general, most of the yield components were favourably affected by nitrogen fertilization from an early stage of growth, but the stem length and tuber yield did not respond significantly until the end of the growing season. Similar results were obtained by Gunasena and Harris (1969) who reported an increase in yield components leaf and stem yield responding to high rates of nitrogen from an early stage of growth, with tuber yields responding later in the growing season.

Most of the tubers appear to have been initiated over a period of about three weeks. The differences in tuber yield and number may therefore be attributed to nitrogen and spacing treatments. High nitrogen levels have the effect of accelerating haulm growth at the expense of tuber bulking while close spacing introduce competition for carbohydrate translocated from the leaves to the tubers. The reduction in number of tubers at later stages of growth may be due to resorption of some tubers after initiation. Similar observations have been reported by Moorby (1967) and Krijth (1955).

Tuber initiation started with variety B9462-1 before variety BR63-18. In both varieties, non-nitrogen treatments initiated tubers before nitrogen treatments. No difference was noticed between plots receiving 60kg N/ha and those having 120kgN/ha. Although tuber initiation may start about the same time with high as well as with low levels of nitrogen, the amount of carbohydrate available for the tuber during early periods of growth for high levels of nitrogen is less.

Nitrogen fertilization had a significant effect in increasing the total yield. With 0 kgN/ha tuber bulking started earlier and ended much earlier too than with 60 and 120kgN/ha. The effect of nitrogen here was to increase the period available for bulking. In the potato crop, after tuber initiation, there is sharing of carbohydrates produced in photosynthesis between the haulm and tubers. As a result of this, if the haulm growth is excessive as is usually the case with high nitrogen levels, tuber bulking suffers especially in the early part of the season. With high nitrogen content in the soil, much haulm growth is obtained, but as the nitrogen is depleted, there is a reverse in the use of assimilates. The bulking rate of tubers then increases. If the crop stays long enough in the field without any adverse conditions such as disease and weather, the high nitrogen crop out-yields lower levels of nitrogen crop. In this experiment, there was an

obvious difference in yields of treated and untreated plots, but the yields from 60 and 120kgN/ha were not too different probably because the growth of crops from 120kg N/ha plots was disrupted by the occurence of disease. The effect of nitrogen on total yield can best be described using the linear equation 182.4 + 34.6x. The coefficient of determination ($R^2$) was significant and revealed that 80.06% and 99.28% of the total variability were accounted through linear and quadratic functions of the data, respectively. The linear response was thus a better measure of regression as it accounted for 80.06% of the total.

Grades of tubers falling below and above 40mm was affected by the application of nitrogenous fertilizer. There was however no significant difference between, 60kgN/ha and 120kgN/ha probably due to the shortening of the potential growth period of crops with high nitrogen level. The number of tubers in the grade of $\leq$ 40mm was more than tubers of $>$40mm in diameter.

There was a non-significant effect on DM% with increase in nitrogen level. This result conforms with the findings of Widdowson et al. (1974) who observed that nitrogen rates of upto 560kg/ha were not detrimental to the DM content of tubers. This is however contrary to the findings of Van Burg (1967) who reported a decrease in DM content with increase nitrogen level.

The results of this experiment indicate a non-significant effect of nitrogen on the starch content of tubers. Hunnius et al. (1978) got similer results using 100- 120kg N/ha.

Only the CP content was affected significantly by nitrogen, spacing and variety, although there was no significant interaction effects among treatments as regards this character. The CP% was analysed on wet basis and this showed a significant increase with increase in nitrogen level. Several workers have reported an increase either in total N% or CP% with nitrogen fertilization (Westerland, 1969; Dyson and Watson, 1971; Talley, 1983). This may be explained by the fact that as the nitrogen content of the soil is increased, more of it is being taken up by plants, thus reducing competition. Tubers from higher levels of nitrogen then end up with more nitrogen in them than those from Okg N/ha level.

## 5.2 Effect of Spacing on Plant Growth, Yield and Quality of Tubers

The growth and yield in the field indicated two kinds of competition as a result of spacing. Competition between plants which may be important at close spacing and competition within plants (between stems) which is significant at wide spacing and with large number of stems. Beukema and van DER Zaag (1979) reported that

if high yield/plant is desired then plant spacing should be wide whereas if high yield/ha is required then spacing should be close.

The main effect of spacing on the vegetative growth of the plants can be attributed to the differences in light interception at different spacings. For example at wide spacing the leaf surface is much smaller and light interception is inadequate so fewer tubers may be produced. An important explanation for higher yields at close spacing is that more leaves, branches and stems are produced per unit area resulting into rapid cover of the soil. With the high leaf area of closely spaced plants, more radiation is intercepted by the foliage for conversion into DM. Adequate ground cover also helps in reducing the amount of radiation heating the soil surface. With varieties that do not have fast early growth as was the case with variety 8R63-18 close spacing of plants will help to produce an early ground cover for better interception of light.

The decrease in dry weights/plant with decrease in spacing must have been as a result of competition between plants for light, nutrients and water. The rapidity of leaf growth in variety B9462-1 during the early part of the growing season indicate that the climate of Zaria is well suited for the production of high yields. The dry matter acumulation was slow during the early part of the season. This increased by

mid season and then reduced again in the later part of the season.

Decreasing plant spacing increased LAI significantly throughout the season. This is in agreement with the results of Ifenkwe and Allen (1978). With more plants per unit area, there was a better spread of leaves to cover the ground. This good ground cover which comes early in the season at close spacing gives rise to high LAI values indicating a larger leaf area available for the production of assimilates. Provided the 'sink' has been well established in good time, the bulking rate of tubers will be high.

There was an increase in total yields with decrease in spacing. The coefficient of determination ($R^2$) was significant when polynomial curves were fitted to describe the data. Values of the coefficient of determination revealed that 93.94% and 99.99% of the total variability were accounted through linear and quadratic functions of the observed data. The linear response was therefore a better measure of regression as it accounted for 93.94% of the total. Only the linear response was significant using the 'F' test of significance, so the data is well represented using the linear equation (192.447 + 33.515x).

Ware as a proportion of total yield also increased with decrease in spacing distance. The yield from 20 and 30cm spacing were similar therefore the little

difference could have been as a result of a difference in duration of bulking. Similar findings were reported by Bremner and Taha (1966). Findlay and Sykes (1938), Bremner et al. (1951) and Murr (1974) also reported a decrease in the yield of small sized tubers with increase in spacing between plants. Increase in the number and size of the tubers with wide spacing did not compensate for the reduction in number of plants, therefore there was a reduction in total yield as spacing distance increased. The increase in the proportion of total produce falling into the ware grade with increased spacing may also be considered in the light of tuber number per unit area. Although tuber number per plant increased as spacing increased, the closely spaced plants had a considerable advantage in tuber numbers per unit area leading to more intense inter-tuber competition and restriction in tuber size.

Spacing had no significant effect on the DM% and starch content of tubers although there was a tendency for these properties to increase slightly with decreasing plant spacing. With decreasing plant spacing, there was a significant effect of decreasing CP%. This effect was due to the more intense competition between tubers for the nitrogen taken up by plants.

## 5.3 Effect of Variety on Plant Growth, Yield and Quality of Tubers

Variety B9462-1 had longer stems than BR63-18. The longer stems encouraged lodging which was not found in variety BR63-18. Plants of this latter variety had a more upright habit than the former variety. Only late in the season was there any significant difference in the leaf number of the two varieties, Variety BR63-18 had more leaves significantly than B9462-1. This may be because leaves of variety B9462-1 were aging fast then and were more affected by disease than leaves of variety BR63-18.

The growth pattern of both varieties was similar only that variety B9462-1 had earlier ground cover, reached the peak growing period faster and matured earlier than variety BR63-18. For most of the growing season, variety B9462-1 produced significantly higher dry weights than the other variety. The LAI values were only significantly different for both varieties during five and seven W/E, coinciding with the peak period of leaf production. The assimilates produced by the leaves are distributed between the haulm and tubers. For variety BR63-18. it appeared a greater proportion of the assimilates was used for haulm growth in the later part of the season than the other variety. The significantly higher LAI values obtained by variety B9462-1 may be as a result of the large leaf size of this

variety which produced a good ground cover early in the season.

After tuber initiation the bulking rate of B9462-1 was faster than for variety BR63-18 and the tubers reached maturity faster too. The bulking rate of tubers of variety BR63-18 was probably adversely affected by the flowering habit of the crop. This is in line with the findings of Proudfoot (1965) who observed that flowering and fruit formation depresses tuber yield. Much of the assimilates that would have been used in bulking was used in flowering and fruiting. Towards the last weeks the flowers and fruits formed a substantial part of the dry matter while most of the tubers were much less than the 40mm size.

Variety BR63-18 produced a higher number of tubers than variety B9462-1. This may be attributed to the fact that the former variety had more number of stems per plant and since each stem is capable of producing tubers more number of tubers were produced per plant. It was therefore normal that at each spacing variety BR63-188 would have more tubers although this means more tubers falling in the small size grade as a result of competition for light, nutrients and water. Variety B9462-1 had more tubers with decreasing spacing mainly because with increase in plant population there is more interception of light. At low densities where competition for light would be minimal the weight of

tubers per unit area would be well below the potential of a crop with a complete canopy. This agrees with the work of Thompson and Taylor (1974).

Chapter 6

## SUMMARY AND CONCLUSION

The experiment was carried out at the Ahmadu Bello University Farm, Samaru, Zaria, during the 1984 rainy season. Treatments consisted of three nitrogen levels, three spacings and two varieties, which were laid out in a randomized complete block design with factorial arrangement.

Nitrogen fertilization had a remarkable effect on the vegetative growth of potato. The number and dry weights of leaves and stems, and plant height were increased with the application of nitrogen fertilizer. The yield of tubers was significantly increased by [illegible] nitrogen and the linear response of nitrogen was a better measure of regression when compared to the quadratic response. 60 kgN/ha increased the tuber yields by 50% over no nitrogen; high level of nitrogen (120 kgN/ha) did not differ statistically from 60kgN/ha. The DM and starch contents were not significantly affected by nitrogen while the CP content was increased by it.

Spacing also had an effect on potato which was most obvious on the yield and size of tubers. The 20cm spacing produced the highest yield of tubers. A linear response of spacing best measures the regression. The closest spacing produced the highest number of tubers/unit area and yields of the different grades were increased with close spacing. The 30 cm spacing appeared to be the best spacing from visual observations in the field. The ground cover by

foliage was quite good and it produced a good proportion of tubers falling into the two grades considered. As with nitrogen, spacing did not have any significant effect on the DM and starch content of tubers. The CP content was however reduced with close spacing.

The yields from the two varieties were quite different, with variety B9[illegible]2-1 yielding more than the other variety which had a higher number of tubers/unit area. The CP% of variety BR63-18 was significantly superior to that of variety B9462-1.

Some interaction effects were observed among treatments on some of the growth characters.

It can thus be concluded that Samaru has suitable weather conditions for the production of potato in the wet season provided adequate steps are taken to control diseases. The crop responded well to nitrogen fertilization and close spacing. Of the two varieties, BR63-18 had two points against it, that is, the flowering and fruiting habit which greatly reduced yields and its long duration in the field which makes it open for disease attack for a longer period, thus its unsuitability as a wet season crop.

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Appendix 1. Physico-chemical properties of soil at experimental site.

| Soil Characteristics | Soil Depths (cm) | |
|---|---|---|
| | 0 - 15 | 15 - 30 |
| pH in water | 5.00 | 5.10 |
| Organic carbon (%) | 0.71 | 0.62 |
| Total nitrogen (%) | 0.06 | 0.34 |
| Exchangeable bases (meq/100g soil) | | |
| Ca | 2.25 | 2.28 |
| Mg | 0.76 | 0.78 |
| Na | 0.12 | 0.12 |
| K | 0.33 | 0.35 |
| CEC (meq/100g soil) | 4.00 | 4.20 |
| Available phosphorus (ppm) | 7.0 | 7.0 |
| Particle size % | | |
| Sand | 50.00 | 54.00 |
| Silt | 32.00 | 30.00 |
| Clay | 18.00 | 16.00 |
| Textural class | Sandy loam | |

Appendix 2. Meteorological data for period May to October 1984 at Samaru.

| Month | Week | Rainfall (mm) | Mean RH(%) | Mean Temp.(°C) | Sunshine(hours) |
|---|---|---|---|---|---|
| May | 1 | 39.0 | 53.9 | 27.3 | 8.0 |
| | 2 | 20.6 | 61.7 | 26.7 | 7.0 |
| | 3 | 25.0 | 61.6 | 26.7 | 8.2 |
| | 4 | 13.8 | 60.6 | 26.1 | 7.4 |
| June | 1 | 6.3 | 72.4 | 26.1 | 6.2 |
| | 2 | 38.5 | 71.6 | 26.0 | 7.4 |
| | 3 | 10.6 | 72.9 | 26.4 | 8.5 |
| | 4 | 0.0 | 68.6 | 25.3 | 7.0 |
| July | 1 | 18.9 | 78.9 | 24.4 | 7.7 |
| | 2 | 41.9 | 75.1 | 24.2 | 5.0 |
| | 3 | 14.6 | 79.7 | 23.5 | 7.0 |
| | 4 | 54.4 | 81.0 | 23.6 | 6.3 |
| August | 1 | 23.3 | 76.7 | 24.6 | 8.1 |
| | 2 | 56.8 | 76.1 | 24.4 | 7.0 |
| | 3 | 45.1 | 76.9 | 24.5 | 9.5 |
| | 4 | 6.3 | 75.4 | 25.1 | 8.4 |
| Sept. | 1 | 61.7 | 81.4 | 23.7 | 6.3 |
| | 2 | 0.0 | 72.9 | 24.6 | 7.4 |
| | 3 | 61.2 | 73.4 | 24.8 | 6.8 |
| | 4 | 30.6 | 73.6 | 24.4 | 7.5 |
| Oct. | 1 | 64.0 | 73.9 | 25.0 | 7.2 |
| | 2 | 60.5 | 55.3 | 23.7 | 8.0 |
| | 3 | 53.0 | 75.3 | 25.2 | 8.0 |
| | 4 | 0.0 | 32.3 | 23.8 | 5.0 |

Total Rainfall 746.1mm

Source: Meteorological Station, Institute of Agricultural Research, A.B.U., Samaru, Zaria.

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| Cameroon Protestant College Bali, Cameroon | 1976 | 1978 | G.C.E. 'A' level |
| Ahmadu Bello University Zaria, Nigeria | 1979 | 1983 | B.Sc. Agric. (Second upper) |

Post(s) Held Since the Award of First Degree

| Organization | From | To | Position |
|---|---|---|---|
| nil | - | - | - |

Year of Admission for Postgraduate Studies: 1984.

Admission Number: M.Sc./AGRIC./5409/1983-84