EFFECTS OF STARTER RATES OF PHOSPHORUS AND NITROGEN ON THE ESTABLISHMENT AND PRODUCTIVITY OF THE AFRICAN CLOVER CV. MEALTON 5 (*Trifolium quartinianum*).

BY

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DECLARATION

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

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This thesis has been submitted for examination with our approval as University supervisors.

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DEDICATION

To the memory of my late father, Mbugua Kariuki who never lived to see me go to school. My mother, Nancy Wairimu Mbugua, who struggled to see me go to school although she had not done so herself.

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ABSTRACT

A study was conducted at Kabete between October 1999 and July 2000 to determine the effects of starter rates of phosphorus, nitrogen and stubble height on establishment and productivity of African clover (*T.quartinianum* cv. Mealton 5). Soil was analyzed for available phosphorus and total nitrogen before planting and after harvesting. To determine establishment, field plant counts were taken biweekly. Dry matter (taken at 120 and 180 days after planting), nodules per plant, plant cover and plant height (taken biweekly) were used to determine Mealton 5 productivity. Percent leaf crude protein (taken after the final harvests) was used to determine nutritive quality of the clover. Weather elements for the entire study period were recorded. The experiment was laid out in Randomized Complete Block Design (RCBD) in three blocks with four treatments. These were:-control (P_0N_0), nitrogen alone at 27 kg N/ha as urea (46 % N) (P_0N_1), phosphorus alone at 30 kg P/ha as Triple super phosphates (TSP) (20 % P) (P_1N_0) and a combination of phosphorus and nitrogen at 30 kg P/27 kg N per hectare (P_1N_1). First experiment was carried out from October 1999 to April 2000, while the second one was from January 2000 to July 2000. Four growth stages were observed in the growth life of this clover. Weather conditions affected the performance of this clover. Seed germination was 90-95% 11 days after the experiment was initiated. Plant field establishment was enhanced more by application of both nitrogen and phosphorus than application of each fertilizer alone. Seedling counts declined with time due to mortality. Plant cover was highest in TSP alone and TSP plus urea treatments from mid–second quarter of growth until final harvest. The control treatment had the poorest cover throughout. The same trend was observed in plant height. Decline in cover in the fourth quarter was possibly due to leaf fall.

Nodules per plant were significantly (P=0.05) increased by phosphorus application. They were highest in TSP alone followed by TSP plus urea. Control and urea alone, respectively had fewer nodules. Dry matter yields were significantly (P=0.05) increased by phosphorus application while urea alone had lesser effect. Cutting height had no significant effects. Percent leaf crude protein was significantly (P=0.05) higher in fertilized plots than in the control. There was an increase in soil nitrogen with fertilizer application after harvesting clover than before planting. This was enhanced by phosphorus application. An increase in soil available phosphorus was observed after harvesting plants under TSP alone and TSP plus urea treatments. Correlation among variables was generally positive. Several of the variables are mostly definitely associated with dry matter yields in Mealton 5.

Application of phosphorus at 30 kg P/ha as Triple super phosphates (TSP) or phosphorus plus nitrogen at 30 kg P plus 27 kg N (as urea) per hectare gave the highest dry matter yields and percent leaf crude proteins as well as soil nitrogen and phosphorus content under conditions of this study.

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LIST OF ABBREVIATIONS

BNF:	Biological nitrogen fixation
CAN:	Calcium ammonium nitrate
CM:	Centimeter.
DAP:	Days after planting.
DAPP:	Days after planting appraisal period
IPAR:	Intercepted photosynthetically active radiation
KG:	Kilogram.
N:	Nitrogen.
P:	Phosphorus.
P1N1:	TSP plus urea treatment at 30 kg /27 kg /ha
P1N0:	TSP alone treatment at 30 kg P/ha.
P0N1	Urea alone treatment at 27 kg N/ha.
P0N0:	No fertilizer applied (control)
PPM :	Parts per million.
TON:	Tonne.
TSP:	Triple super phosphate.

CHAPTER ONE: INTRODUCTION

A small holder farmer in central highlands can successfully establish African clover cv. Mealton 5 with moderate phosphorus and nitrogen fertilization. Cultivar Mealton 5 is a newly developed strain of *Trifolium quartinianum* Ecotype 1. Ecotype 1 was identified as promising from a collection of annual African clovers from East African highlands (Akundabweni, pers. comm.). Cultivar Mealton 5 was developed as an annual fodder crop for small holder systems in central highlands on the basis of the following attributes: It has high dry matter productivity. It is suitable in intensively cultivated systems, as it is compatible with food crops on rotation and can be undersown with food crops. It has a very low persistence and can be easily eradicated when land has to convert to food crop production. It can be a suitable cover crop and a source of nitrogen through biological nitrogen fixation (BNF) and in enhancing edaphic environment. As a cover crop, it has potential for minimizing soil erosion. It is highly nutritive with high crude protein, digestible stem and high leaf: stem ratio. It can thus be an important complement to nappier grass. Generally it is free from pests and diseases and does not have toxic substances. It is highly palatable and has no reported antiquality substances (Akundabweni, 1998).

Mealton 5 is highly productive when it has successfully established. Successful establishment is achieved through correct seed scarification for rapid germination, correct seeding depth and when seeds are intimately in contact with the soil on a well-prepared seedbed. Other prerequisites for successful establishment are adequate soil fertility and adequate moisture (the soils do not necessarily have to be free-draining). The clover must nodulate effectively (Akundabweni, unpublished). Adequate soil fertility can be achieved through choosing a fertile site either naturally from previous history of farm management, sound husbandry practices or through inorganic application of phosphorus and nitrogen (Tisdale *et al.*, 1993).

Nitosols (Kikuyu red loam) are widespread in central highlands particularly in ecozones referred to as Kikuyugrass/tea zone. Other important soils include Andosols. Nitosols have a fairly low pH and low phosphorus and nitrogen. In intensively cultivated systems, the cut and carry method (zero grazing) tends to remove the phosphorus and nitrogen from the soil leading to "soil mining". It creates a need to improve the soil for further successful establishment of subsequent crops (Boonman, 1993). When Nitosols are depleted of nutrients, the establishment of Mealton 5 can be expected to be poor. These soils can be improved by restoring them to good fertility naturally; use of biological nitrogen fixation (BNF) species has a significant contribution towards that end. This dimension alone is equally beneficial to establishment of Mealton 5. Secondly, use of inorganic fertilizers such as phosphorus and nitrogen can rapidly restore poor fertility soils. These two essential nutrients favour the establishment, high productivity and nutritive value of Mealton 5.

Kayinde (2000) recently found that the Mealton 5 as mulch rapidly decomposed within 120 days (under controlled conditions). Within the first year, a bean crop benefited from rapid mulch decomposition. Mealton 5 clover itself planted as a subsequent crop on the same mulch also gave better yields than a control. Results thus show that Mealton 5 can directly benefit from its own natural fertility (zero inorganic fertilizer application). Earlier results by Akundabweni (1984b) have shown that inorganic quantities of these essential nutrients are extremely effective in successful establishment of a number of annual African clovers including Mealton 5.

Fertilizer application is effective in promoting successful establishment when applied during planting time. It promotes higher seedling survival after emergence and rapid development of nodules before the plant is able to fix its own nitrogen. There also seems to be a certain extent of the use of a part of total phosphorus possibly due to mychorrizal association in the clover. As Akundabweni (1984b) found, the annual clovers were highly responsive to low levels of applied phosphorus (in a triple superphosphate (TSP) form) on soils that showed high total phosphorus.

Successful establishment of Mealton 5 on Nitosols in Kabete fluctuates when moisture is erratic and in particular when the fertility status is low (Akundabweni and Njuguna, 1996). Under farmers' cultivation, conditions, fertilizer and moisture availability could determine the crop's success or failure. In less ideal conditions, Mealton 5 is likely to produce low dry matter as well as reduced seed yields. Being a shy seed producer, a further reduction in the latter can be quite drastic.

1.1 Hypothesis and Justification

The question arising is whether Mealton 5 under the farmers' practices can perform consistently well if starter phosphorus and nitrogen are provided and water is available. The following work is an invaluable contribution towards a future development of a farmer's manual since this clover has not yet fully entered cultivation.

It is against this background that two experiments were set up in Kabete in 1999-2000 to determine the singular and combined effects of starter rates of phosphorus and nitrogen on establishment and productivity of Mealton 5 with the following overall objective:

(1) To find out the effects of starter rates of phosphorus, nitrogen and cutting height on establishment and yield of Mealton 5.

The specific objectives were (a) To determine the effects of starter rates of phosphorus and nitrogen on the following variables: plant field establishment, plant height, plant cover, nodules/ plant, dry matter yield (DM) and leaf crude protein (CP).

(b) Determine effect of stubble height on DM; and (c) To investigate the phenological stages with respect to growth performance.

CHAPTER TWO: LITERATURE REVIEW

2.1 African Clover Legumes in the Highlands of Eastern Africa

The African clovers make about 40 species, many of which are still growing in the wild (Bogdan, 1965). They are distributed in Eastern Africa, Central and some isolated parts of West African highlands. Few are also found in Southern Africa south of Limpopo. African clovers have not penetrated into the local farming systems because of the existing gaps of knowledge about the appropriate agronomic practices.

The highlands support a rich diversity of the African clovers of which agronomic potential has been demonstrated for intensive forage-crop livestock production (Kahurananga *et al.*, 1984; Strange, 1958). These clovers are distributed in the African highlands across a wide range of edaphological soil types present across the uplands and the bottomland catenas (Akundabweni, 1984b). Most members of the African clovers are distributed in the Eastern Africa and cover most parts of Central Ethiopia and smaller parts of the higher plateau in Somalia, Kenya, Tanzania and Uganda (Zohary, 1972; Thulin, 1982; Bogdan, 1956). Ethiopian highlands represent the largest diversity in Eastern Africa. About 8 to 10 perennials and numerous annual species occur in the Ethiopian region alone (Thulin, 1982). In total, about 40 different species occur in Africa south of Sahara, which makes Africa an important source of clover germplasm, besides the Mediterranean and the North American subcontinent (Zohary, 1972).

Distribution of clovers in the East African region is traced back to their original migration via the Afro-Alpine Mediterranean pathway almost 50 million years ago (Zohary, 1972). Since then, they have become common highland components of the natural grassland pastures in the region. It is for this reason that many natural grassland pastures in Ethiopian highlands are rich in species as described by Thulin (1982).

The East African highland clovers have their greatest promise for exploitation in the favorable agricultural zones of the East African highlands (Akundabweni, 1984a; Gillet, 1952). Highland pastures have potential for intensive form of cultivated forage production with the highest area: yield ratio (Strange, 1958). The East African highland clovers have further been shown to significantly enhance the nutritive quality of crop residues (Mosi, 1983). Some of the African clovers in the annual category have shown good fodder yield potential, good nutritive potential for hay (Kahurananga and Tsehay, 1984) and economical seed production (Akundabweni and Njuguna, 1996). The annual *Trifolium quartinianum* cv. Mealton 5 is a recent selection in part based on the above attributes.

The *Trifolium* genus in Africa contains twice as many annuals as perennial clovers. Biennials are absent (Gillet *et al.*, 1971). Although the growing period of the former is shorter than that of the perennial, the high dry matter yield of annuals could be of greater use if harvested and conserved to overcome the seasonal food shortage. Annual clovers could be conveniently integrated into the existing crop and livestock enterprises with greater management flexibility than might be the case with perennial African clovers (Akundabweni, 1984b).

2.2 Role of Mealton 5 in Intensive Farming Systems.

T. Quartinianum, T. tembense and T. steudneri among other African annual clovers have shown quite high dry matter yields with good nutritive potential for hay (Akundabweni, 1984b; Kahurananga and Tsehay, 1984) and economical seed production (Akundabweni and Njuguna, 1996; Akundabweni, 1984b).

Call for integration of forage legumes with livestock production has been accompanied by a suggestion that the key to increased livestock production in sub-Saharan Africa is inter-cropping legumes and cereals. This is because of high dependence of livestock on crop residues in the long dry season. Advantages of such an inter-cropping are:-

(1) possibility of nitrogen accretion from the legume to the cereal; (2) maintenance of continuity of feed supply during the dry period; (3) more efficient utilization of low quality cereals through the addition of high quality forage; (4) return of manure from livestock to the field and (5) greater dependability of returns compared to the sole cropping (Gryseels and Anderson, 1983). Yields of corn, small grains and forage grasses are often increased when they are grown in combination with legumes (Tisdale *et al.*, 1993) partly due to improved nitrogen supply for non legume plants.

Due to intensive cultivation in the central highlands and the cut- and- carry method, soil nutrients are quickly depleted. Nitosols are generally poor in phosphorus and nitrogen, which are the critical elements in crop production (Mokwunye *et al.*, 1986; Warren, 1992; Sanchez, 1976). Though they might be applied in inorganic form, the cost is generally too high for the most smallholder farmers to afford. Ameriolation of soil nitrogen through biological nitrogen fixation (BNF) is a good option for impoverished farmers. There is, thus, reason for using leguminous cover crops in rotation and inter-cropping systems to obtain sustained high crop yields at minimum fertilizer cost.

The amount of nitrogen fixed by properly nodulated legumes averages about 75 percent of the total nitrogen used in the growth of the plant (Tisdale *et al.*, 1993. Maximum benefits of nitrogen fixation can be obtained by amending soil nutrient shortages with appropriate mineral fertilizer (Boonman, 1993; Horst, 1986). Seeds can also be inoculated with efficient strains of *Rhizobia* prior to planting (Boonman, 1993; Horst, 1986). However, on most East African soils *Trifolium quartinianum* is capable of fixing its nitrogen biologically, thus improving the soil nitrogen status naturally thereafter (Akundabweni, pers. comm.). Its plant cover provides a natural mulch in either preventing soil erosion or enhancing the health of the plough layer (Kayinde, 2000). Its extensive root system holds the soil particles together thus, reducing soil erosion (Wondafrash, 2000).

Nitrogen fixing legumes are important once they are inter-cropped or rotated with cereals as they fix nitrogen and leave it in the soil for the succeeding crop to use (Boonman, 1993; Tisdale *et al.*, 1993; Sanchez, 1976). In the intensively cultivated systems where crop and livestock are raised, clover legumes confer high quality animal feed, while enhancing cereal crop production (Kayinde, 2000). *T. decorum*, another promising annual clover plays a very important role in boosting grain yields of cereals in rotation in Gojam area of Ethiopia (Murphy, 1968).

Elsewhere, studies showed that inter-cropping wheat and clover (*T. quartinianum or T. steudneri)* or sequential cropping of an oat/vetch mixture followed by chickpeas provided high quality fodder (Tedla *et al.*, 1999). The effect was more pronounced under fertilized conditions. Where monocropping had been practiced, legume-cereal rotations led to higher grain and fodder yields compared to cereal-cereal rotations.

Mixtures of legumes and cereal forages improve percent crude protein and *in vitro* dry matter digestibility (IVDMD) of the mixtures, because legumes have higher percent crude protein and better digestibility than grasses (Boonman, 1993; Keya *et al.*, 1971)). Elsewhere, grass-legume mixture accumulated more dry matter, crude protein and *in vitro* digestible dry matter than grass monocultures (Gebrehiwot *et al.*, 1997). Dry matter yield of C_4 grass-legume mixtures increased by 70 percent. Crude protein concentration increased by 32 percent. *In vitro* dry matter digestibility (IVDMD) increased by 7 percent. In the C_3 grass- legume mixture, dry matter yield increased by 25 percent whereas crude protein increased by 15 percent. However, there was no improvement in IVDMD between mixtures and C_3 grass monocultures. Elsewhere, although a non-clover legume woolypod vetch increased yield and crude protein concentration of the mixtures more than the clovers, while the latter increased IVDMD of the mixtures more than woolypod vetch (Hagedorn *et al.*, 1991). Legumes are also valued for their high content of minerals particularly calcium, sulphur and phosphorus (Whiteman, 1980). Tekalign *et al.* (1994) found that when wheat (bread and durum) were undersown with clovers (*T. steudneri, T. rueppellianum, T. quartinianum, T. decorum and T. tembense*), wheat grain yield was not reduced. Fodder yield and quality (crude protein and IVDMD) increased in wheat straw-clover mixture, while its NDF reduced compared with the pure stand of wheat.

FAO (1983) noted that the major constraints to increased animal production are malnutrition caused by either low protein forage or overstocking. Tothill (1986) has summarized potential use of forage legumes in intensive farming systems and particularly in livestock nutrition. Mosi (1983) found that inclusion of *T. tembense* hay to maize stovers or teff straw increased total feed intake, total dry matter retention and dry matter digestibility of the combined feed. Olayiwole *et al.*, (1986) observed that *T. tembense* enhanced nutritive quality of alkaline-treated crop residues in feeding trials with sheep.

2.3. Effects of Climate and Soil on Establishment and Productivity of Mealton 5

2.3.1 Rainfall

The higher the rainfall and the longer the duration of available moisture, the better the clovers continue to grow, mature later and thus yield more than if the moisture available duration was shorter (Akundabweni *et al.*, 1991). Mealton 5 has persistently performed best under adequate moisture conditions. Generally, at least 1000 mm of rainfall are needed for forage production for most of the annual clovers (Kahurananga and Tsehay, 1991). In fact, several trials have shown that Mealton 5 will fail when rainfall is inadequate. Akundabweni and Njuguna (1996) proposed that the number of moist days after planting is more important on the management of clovers for optimum productivity than calendar days after planting as the distribution rather than intensity seems to be more of a critical consideration.

Wondafrash (2000) studied this proposition and found that *T. quartinianum* cv. Mealton 5 performed best at 50 percent monthly pot soil moistening/wetting frequency during its 5 months maturation span. Mealton 5 is therefore likely to do well in the UH1, UH2 and parts of UM1 agroecological zones, which are characterized by sustainable rainfall distribution across at least 4 –5 months of a growing season (Akundabweni, pers. comm.).

On the other hand, Mealton 5 is likely to fail under unfavorable moisture conditions. Establishment and productivity of Mealton 5 is adversely affected by moisture scarcity. Seedling mortality occurs early in the planting season after emergence if moisture is erratic. This leads to poor stand establishment. Previous field observations (Akundabweni, unpublished; Hagedorn *et al.*, 1991) have shown that moisture stress during vegetative growth period leads to slow growth and low final dry matter yields. Plant canopy does not develop much and this reduces plant cover and photosynthesis, as the light harvesting leaf area is reduced (Fitter and Hay, 1987). This leads to reduced BNF, because the whole process of photosynthesis is reduced, and so less photoassimilates are available to the nitrogen fixing bacteria (Haystead and Sprent, 1981; Havelka *et al.*, 1982; Horst, 1986). Water stress was found to cause severe inhibition of nitrogenase activity and nodule respiration in a number of legumes (Bergerson, 1977; Venkatswarlu *et al.*, 1990). Moisture stress during flowering led to production of few flowers and resulted in low seed yields (Akundabweni and Njuguna, 1996; Garstel and Kerley, 1988). In effect, moisture stress causes such plants to cease growth earlier and this leads to low final yields.

Temperature is also an important factor. It interacts with photoperiod to affect flowering of some African clover species, making it difficult to draw a clear line between long and short-day plants (Joffee, 1962). Effects of temperature alone, however, are probably important as a regulatory rather than a selective force (Mannetje, 1964). More directly, temperature differences associated with moisture deficits appear to significantly influence growth patterns in Mealton 5 (Akundabweni *et al.*, 1991). Cooler March rainfall period temperatures during peak rain depressed yields. Across the March rainfall period – June rainfall period, warmer cloudless periods and prolonged moisture duration increased yields (Akundabweni and Njuguna, 1996; Akundabweni *et al.*, 1991; Kayinde, 2000).

2.3.2 Soils

Phosphorus and nitrogen are the most limiting nutrients in Mealton 5 performance (Akundabweni, 1984a). Norris (1965) characterized tropical legumes as species which probably evolved under conditions of low soil nutrient status and high acidity. He found that Oxisols, Ultisols and Vertisols from various tropical countries have low phosphorus levels ranging from 20 to 200 PPM. In view of the studies by Norris (1965), African clovers among other species may have evolved under low soil nutrient status. In line with this fact, Akundabweni (1984a) demonstrated significant responsiveness of *T. quartinianum* to between 10 and 25 kg P/ha. on a Vertisol in Addis Ababa, Ethiopia.

Sanchez (1976) observed that some legumes on low phosphorus soil respond dramatically to fertilization and do not require as much phosphorus as grasses. Andrew (1976) found that nodulation still persisted, although it was reduced at pH 4.0 which further corroborates Norris' (1965) observation of high acidity tolerance among tropical species. Andrew (1973) found that *T. rueppellianum*, another annual clover had high tolerance to aluminium toxicity due to the plant's ability to absorb and translocate phosphorus despite the presence of aluminium.

Tropical soils generally have high levels of sulphur. Nutrient deficiency is, therefore, more likely to be due to low phosphorus than to lack of sufficient sulphur levels (Mokwunye *et al.*, 1986; Warren, 1992; Sanchez, 1976). Soil phosphorus deficiency may be due to low phosphorus status in parent material, weathering, long term anthropogenic mismanagement, phosphorus loss by erosion and surface runoff (Fairhurst, 1999).

Soil fertility is crucial for establishment and productivity of Mealton 5. A fertile site with adequate amounts of nitrogen and phosphorus should be selected for production of this clover. In poor soils, inorganic fertilizer application improves the establishment and productivity of this clover. Soil should be able to retain moisture long enough (> 4 months) as Mealton 5 is very susceptible to lack of moisture. Waterlogging for long is undesirable to nodule-forming legumes (Wondafrash, 2000; Fairhurst, 1999), although Akundabweni (1984b) observed that most annual clovers astonishingly thrived on waterlogged Vertisols in Ethiopia.

Generally, soils that rapidly lose water succumb to drought quickly, leading to poor establishment of Mealton 5 (Akundabweni, 1984b; Akundabweni and Njuguna, 1996). Acrisols and other sandy soils unless irrigated are, thus, not suitable for clover establishment. Nitisols of central highlands are slightly acidic with a pH range of 5.2-7.7. This pH range does not negatively affect growth and nodulation of legumes (Norris, 1965; Andrew, 1976; Tisdale *et al.*, 1993). Phosphorus and other nutrients are available in this pH range (Fairhurst, 1999; Kamprath, 1969; Tisdale *et al.*, 1993). Most crops, thus, do well in this pH range (Foy and Brown, 1964; Rios and Pearson, 1964; Kamprath, 1967; Kamprath and McCart, 1965). Significant phosphorus fixation occurs due to the presence of sesquioxides in Oxisols, Ultisols and Alfisols (Sanchez and Logan, 1992). In Andosols, severe phosphorus fixation is due to the presence of allophanes.

2.4 Importance of Phosphorus and Nitrogen Fertilizer on Clover Establishment and Productivity.

Most annual African clovers need starter nitrogen to support rapid establishment before BNF commences (Jutzi and Haque, 1984; Tisdale *et al.*, 1993; Horst, 1986). Nitrogen is the most important element driving growth and development in plants (Tisdale *et al.*, 1993). It is important for protein synthesis. Most plant proteins are concentrated in the leaves and include chlorophyll, ribulose bisphosphate carboxylase (RUBP) and phosphoenol pyruvate (PEP) carboxylase, among others. These proteins are important in driving photosynthesis, and thus plant productivity (Tisdale *et al.*, 1993; Horst, 1986). Adequate nitrogen leads to vigorous vegetative growth and dark-green colour. Excess nitrogen leads to prolonged growth period and delayed maturity (Tisdale *et al.*, 1993; Horst, 1986). Crude protein concentration in small grains, grass forages and other crops, is frequently raised by adequate nitrogen nutrition (Tisdale *et al.*, 1993; Horst, 1986).

Nitrogen accelerates rapid development of plant canopies (Tisdale *et al.*, 1993, increases the rate of plant height elongation, thus, leading to a good plant stand. Once nodules develop, they take over the role of providing nitrogen to the plant through BNF. BNF requires phosphorus (Tisdale *et al.*, 1993; Horst, 1986). If nitrogen is applied after nodulation, nodules do not effectively contribute to plant nitrogen (Horst, 1986). Legume nitrogen fixation is at the maximum only when the level of soil available nitrogen is at the minimum (Tisdale *et al.*, 1993). As soil nitrogen level increases beyond a certain level, nitrogen fixation decreases (Horst, 1986; Jutzi and Haque, 1984; Carroll and Gresshoff, 1983). For beans, soil nitrogen level that gives maximum nitrogen fixation is 25 kg N/ha, given as nitrate (Sundstrom *et al.*, 1982).

Nitrogen deficiency leads to chlorosis, stunted growth, slow plant canopy development, early crop maturity, low crop quality and yields (Frank, 1965; Bartholomew and Clarke, 1965; Radin and Parker, 1979; Radin and Boyer, 1982; Tisdale *et al.*, 1993;

Gunasena and Harris, 1971; Nevins and Loomis, 1970; Natr, 1975). Nitrogen deficiency during flowering period enhances flower drop and depresses seed yields (Streeter, 1978; Brevedan *et al.*, 1977). Akuja (1995) found that nitrogen applied at 20 kg/ha, 40 kg/ha or 60 kg/ha, significantly increased leaf dry matter, plant height and above ground biomass of *Trifolium quartinianum* when inter-cropped with finger millet. *Crotalaria brevidens*–millet inter-crops also improved dry matter yield of finger millet. Sole legumes yielded higher than inter-crops when fertilized with nitrogen.

Phosphorus is important for energy storage and transfer. Adenosine tri-phosphate (ATP) is the common energy 'currency' that powers practically every energy-requiring biological process in plants, including BNF (Tisdale *et al.*, 1993; Horst, 1986). Phosphorus leads to early plant maturity, particularly in grain crops (Tisdale *et al.*, 1993; Salisbury and Ross, 1986). Adequate phosphorus nutrition is particularly associated with satisfactory root development (Tisdale *et al.*, 1993; Salisbury and Ross, 1986) and nodulation in legumes (Chauhan and Singh, 1981). Phosphorus deficiency leads to reduced plant growth, delayed crop maturity, slow plant canopy development, reduction in crop quality and yields (Fairhurst *et al.*, 1999; Hecht-Buchholz, 1967; Horst, 1986; Terry and Ulrich, 1973). Gervais (1960) reported that phosphorus fertilizer significantly increased nitrogen concentration in clovers but not in grasses. Kahuro (1990) reported a significant increase in leaf protein due to phosphorus application in runner beans. Increased phosphorus levels promoted nodule initiation, weight and nodule size of the common beans (Keya and Mukunya, 1979). Mahatanya (1977) reported that plant height, pods per plant, pod weight, seed yield per plant and seed yield per m^2 of beans increased with increased phosphorus rate.

Studies, however, have focused on phosphorus alone (Akundabweni, 1984a) on assumption that nitrogen-fixing legumes fix their own nitrogen. Although correct, it is apparent from the foregoing findings that inclusion of nitrogen is a necessary intervention.

African clovers were found highly responsive to modest phosphorus application (Akundabweni, 1984a). Dry matter and seed yields linearly increased when phosphorus at between 10 and 25 kg/ha was applied. This response occurred on a Vertisol. Soil data before the trial showed low available phosphorus (1 PPM). Akundabweni (1984a) proposed that such a response of the African clovers could probably be in part due to natural selection to low soil phosphorus status. Phosphorus boosts the relative growth rates of commercial clovers more than of grasses when added to the soil at the beginning of a growing season (Akundabweni 1984b). n addition to its direct effects, lack of phosphorus also has an indirect influence on legume nutrition in that it limits the formation of nodules and the subsequent fixation and availability of nitrogen (Gates *et al.*, 1973). Application of phosphorus to African clovers leads to increased dry matter yields as well as phosphorus and nitrogen uptake from the soil (Jutzi and Haque, 1984). The single most important factor that limits legume growth and nitrogen fixation is phosphorus (Fairhurst *et al.*, 1999). It has been shown that plants dependent on nitrogen fixation require more phosphorus than plants that use mineral nitrogen (Freire, 1984; Cadisch *et al.*, 1989). This need reflects the vital role of phosphorus in electron energy transfer and the large quantities of energy required for reduction of N_2 to NH_4^+ during biological nitrogen fixation. Nitrogen fixation requires a source of photosynthates and energy for development and maintenance of nodules (Haystead and Sprent, 1981; Pate and Herridge, 1978; Minchin and Pate, 1974).

Haque and Jutzi (1984) found that African clover seedlings established more rapidly with the addition of nitrogen. Higher rates of nitrogen retarded nodule growth and inflorescence formation. The number of inflorescence per plant at the final harvest was reduced, although size of the inflorescence was not influenced by nitrogen application. Pod and seed sizes were not altered by improved nitrogen and phosphorus availability. Thus, phosphorus (and sometimes-other nutrients) is needed to establish and maintain Mealton 5.

CHAPTER THREE: MATERIALS AND METHODS

Studies were done between October 1999 and July 2000 at the Field Station, Faculty of Agriculture, University of Nairobi, Kenya on effects of starter fertilization of phosphorus and nitrogen on establishment and productivity of *T. quartinianum* cv. Mealton 5. The site is situated on latitude $1^0 15'$ S and longitude $36^0 44'$ E at 1942 meters above sea level (Wamburi, 1973). Rainfall is bimodal. Long rains begin in late March and last until June. Short rains follow from October to December. Mean annual rainfall and evapotranspiration are 925 mm and 1363 mm, respectively. The study was established on deep red eutric Nitosols, containing 60 percent clay particles, of which clay mineral is predominantly Kaolin on the parent Trachyte. The pH of the soil typically ranges from 5.2 to 7.2 in the topsoil and 5.2 to 7.7 in the sub soil (Nyandat and Michieka, 1970). Temperature and rainfall data for the months of August 1999 to July 2000 are as given in Fig. 1.

Treatments involved the following: (1) applying phosphorus alone in TSP formulation (P_1N_0); (2) nitrogen alone as urea fertilizer (P_0N_1); (3) their non-compound combination (P_1N_1); and (4) the control (P_0N_0). The experiment was laid out as a Randomized Complete Block Design (RCBD) in three blocks. Phosphorus as Triple super phosphate (TSP) (20% P) was applied at a rate of 30 kg P/ha to give (P_1N_0) treatment. Nitrogen as urea (46% N) was applied at a rate of 27 kg N/ha to give (P_0N_1) treatment. Both fertilizers were combined at 30 kg P/ha plus 27 kg N/ha to give (P_1N_1) treatment. Control plots (P_0N_0) received no fertilizer. First trial was performed between October 1999 and April 2000. Second trial was between January 2000 and July 2000.

Scarified seeds were tested for germination on moist tissue paper in petri-dishes before planting. Germinated seeds were counted 5, 9 and 11 days post-incubation.

Seeds were scarified before planting. They were sown in 2.5-cm fertilizer-treated-furrow rows, which were immediately covered with soil. Seed rate was 10 kg/ha. Plots were weeded regularly. Supplemental water was added whenever required. No pests and diseases were evident.

Weather data for the entire study period was recorded.

Soils sampled using an auger at 0-15 cm depth and 15-30 cm depth were analyzed for available soil phosphorus and total nitrogen before planting and after harvesting. Before analysis, soil samples were air-dried, ground and passed through a 2-mm sieve. Nitrogen was determined using macro-Kjedahl method (Black, 1965), while phosphorus was analyzed using the method of Mehlich (1953).

Field plant counts were carried out in the first 45 days after planting and at 15-days intervals along rows of 15 cm.

For percent plant cover, a sunfleck ceptometer (SF 80 Decagon, Pulman, Washington) was placed below and above the crop canopy and the amount of solar radiation that was intercepted by the crop canopy determined. This was expressed as fraction of radiation above the canopy (Monteith, 1973). The probe was placed perpendicular to the rows and three readings were taken per plot. Readings were taken between 12 p.m. and 1.00 p.m. every 14 days. Data were arcsine-transformed before the analysis.

Aerial dry matter yields were determined at 120 and 180 days after planting. Plants were cut at 5 cm and 10 cm stubble heights above the ground within a 22 cm x 25 cm using a quadrat frame. Fresh weight was determined immediately. The samples were then dried in an oven at 70^0C for 72 hours to a constant final dry weight for dry matter yield determination (AOAC, 1984). Leaves were then separated and re-dried further. They were ground and placed in a macro- Kjedahl digester for leaf crude protein determination.

Plant height was measured on three plants per plot every 14 days by placing a ruler from the ground to the tip-most of the plant.

Nodules per plant were counted every 14 days as well. Three whole plants per plot were carefully dug out and the soil removed by soaking in water to wash off the debris, before counting nodules.

Data were analyzed according to Steel and Torrie (1981). No statistical analysis was done on soil phosphorus and nitrogen because samples were bulked to make one sample for each fertilizer treatment in each experiment. Percentage and fractional data were first arcsine-transformed before the analysis. Fisher's protected Least Significant Difference Tests (LSD) were undertaken where ANOVA F value was significant. Analyses were done by Genstat software (Lawes Agricultural Trust, Rothamsted Experimental Station, 1995).

CHAPTER FOUR: RESULTS

4.1 Sampling Intervals

Sampling intervals (SAI) (each at 14 days apart) were as a result of field observation grouped in a block of periods and are coded as SAI 1- SAI 12. They are as presented in Table 1.

Table 1: Phenological stages based on sampling intervals.

Sampling interval as factors	Interval Duration In			Response Variable
	(Days)	(Weeks)	Months	Stage
SAI 1	14	2	0.5	1 (= early seedling)
SAI 2	28	4	1.0	
SAI 3	42	6	1.5	
SAI 4	56	8	2.0	2nd (= active vegetative growth)
SAI 5	70	10	2.5	
SAI 6	84	12	3.0	
SAI 7	98	14	3.5	3rd (= Mature growth)
SAI 8	112	16	4.0	
SAI 9	126	18	4.5	4th (= Senescent stage)
SAI 10	140	20	5.0	
SAI 11	154	22	5.5	
SAI 12	168	24	6.0	

4 .2 Weather Conditions at the Experimental Site.

Total rainfall during the study period was generally higher than the 10 - year mean for the months of November and December 1999 and June and July 2000 (Fig. 1a). Based on a 10-year mean, total rainfall is generally higher in the March-May period (Long rains) than the November-December period (Short rains). The reverse of the norm was, however, the case during the study period. Instead 'longer' rains appeared to occur during the November-December months of the study period (1999/2000). Outside the two peaks rainfall during the study year was lower than normal (Fig. 1a). Plants in the first trial received high rainfall from planting until active vegetative growth (i.e. between Stages 1 and 2) and towards the terminal senescent stage. Plants in the second trial received high rainfall when they had matured (Stage 3) and in part of the senescent stage.

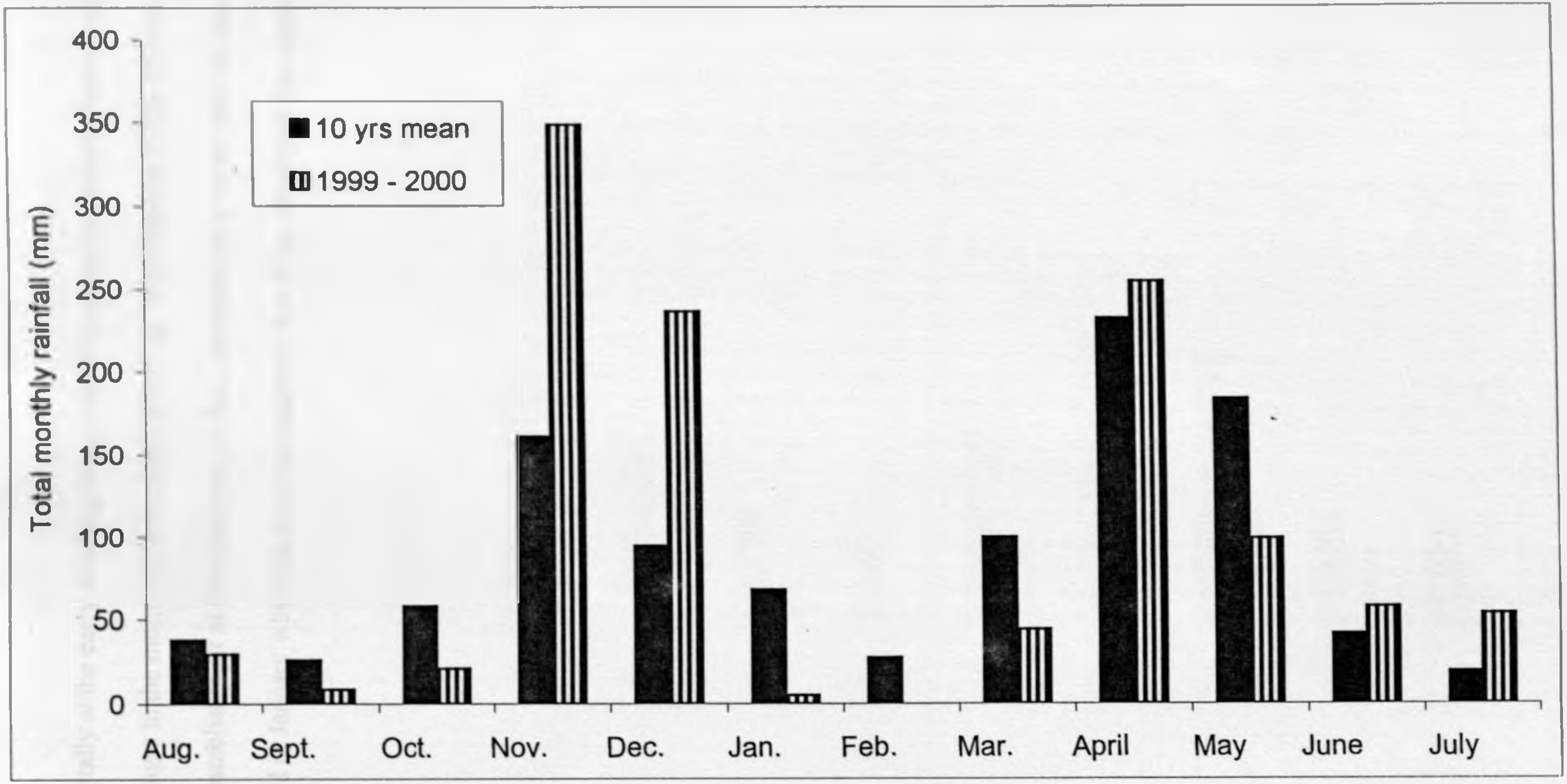


Fig.1a Total monthly rainfall (mm) at the experimental site for the entire study period (Oct. 1999-July 2000) compared to 10-year mean.

Incidentally at the early seedling stage, rainfall duration (number of rainy days per month) was longer in the month of November 1999 (Fig. 1b) compared to the 10-year mean. The first trial establishment at this time was, in fact, comparatively better than the second trial established in January when the rain was relatively low (Fig. b) despite the supplemental watering.

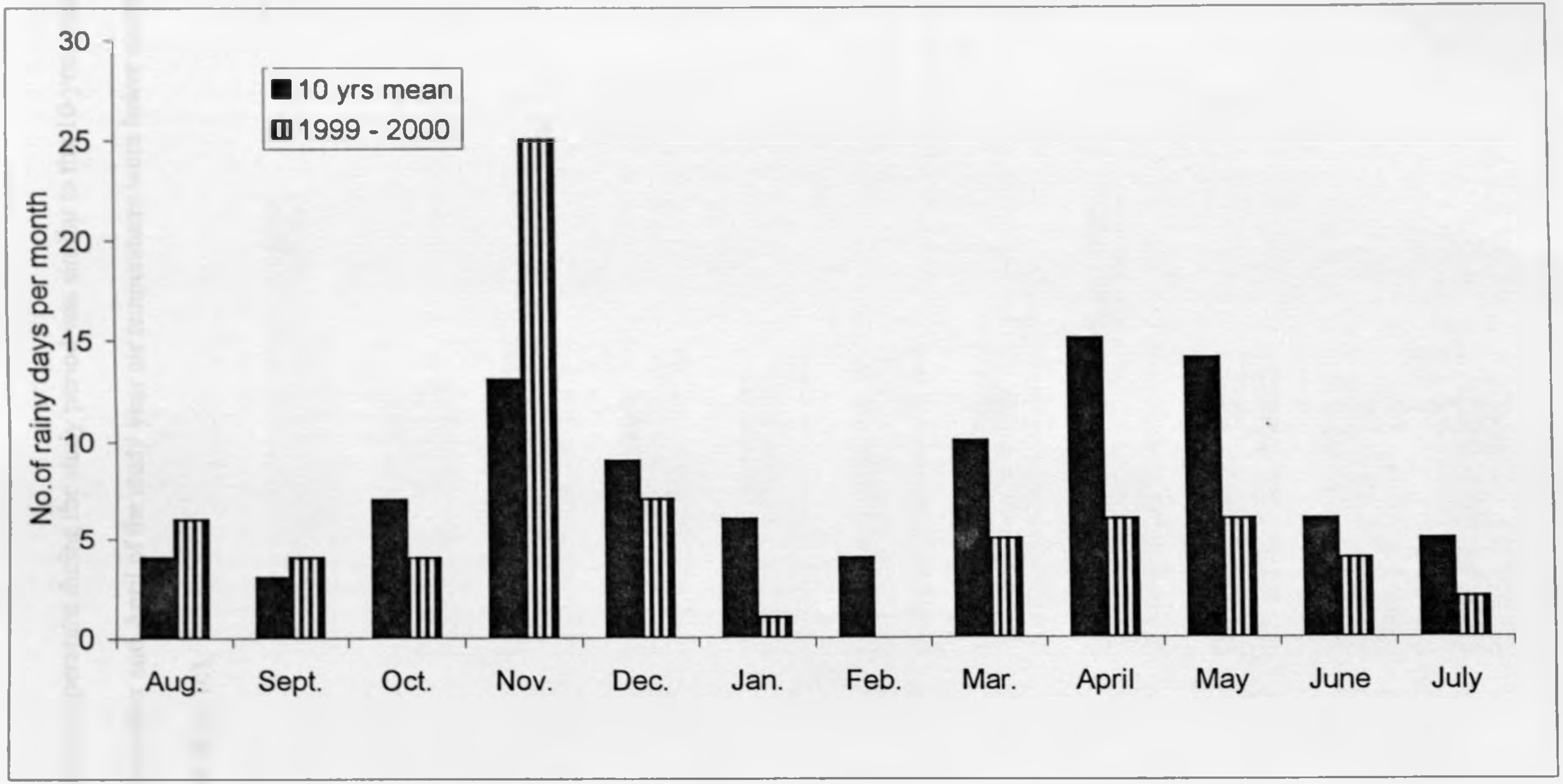


Fig.1b Number of rainy days per month at the experimental site for the entire study period (Oct. 1999-July 2000) compared to 10-year mean.

Average air temperature during the study period was similar to the 10-year mean. However, for September and April of the study year air temperatures were lower compared to the 10-year mean (Fig. 1c).

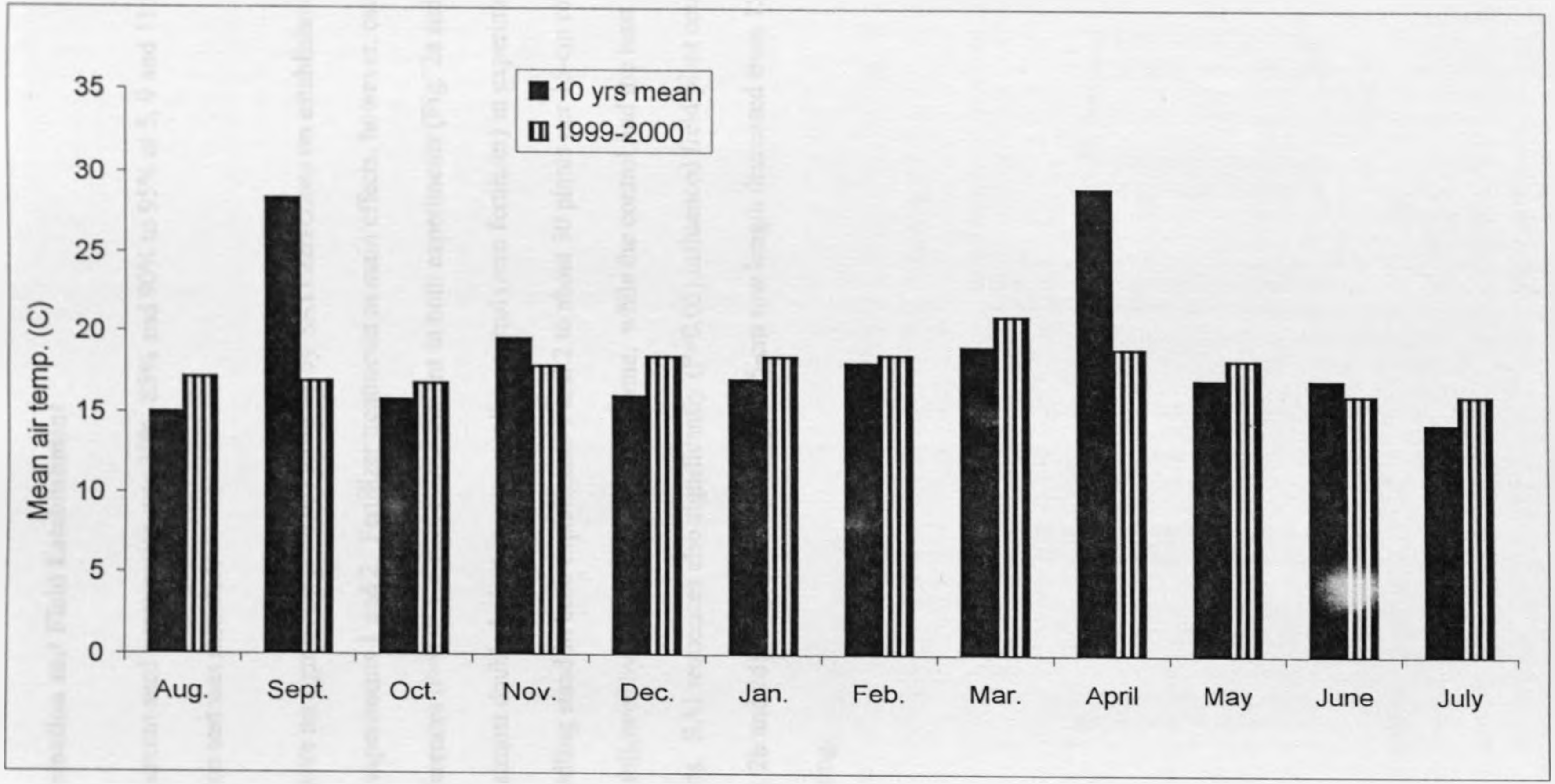


Fig.1c Average air temperature (C) at the experimental site for the entire study period (Oct. 1999-July 2000) compared to10-year mean.

4.3 Seed Germination and Field Establishment

Mean percent seed germination was 30%, 85% and 90% to 95% at 5, 9 and 11 days after germination test was initiated.

There were no significant (P=0.05) fertilizer by SAI interactions on establishment counts in both experiments 1 and 2. Fertilizer treatments as main effects, however, caused significant differences (P=0.05) in field establishment in both experiments (Fig. 2a and 2c). TSP plus urea almost doubled plant counts over the control (zero fertilizer) in experiment 1. It increased seedling stand in both experiments 1 and 2 to about 30 plants per 15-cm row length. It was followed by urea alone, then TSP alone, while the control had the least number of plants. SAI sequences also significantly (P=0.05) influenced field plant counts in both trials (Fig. 2b and 2d). Number of plants per 15-cm row length decreased from 15 to 45 days after planting.

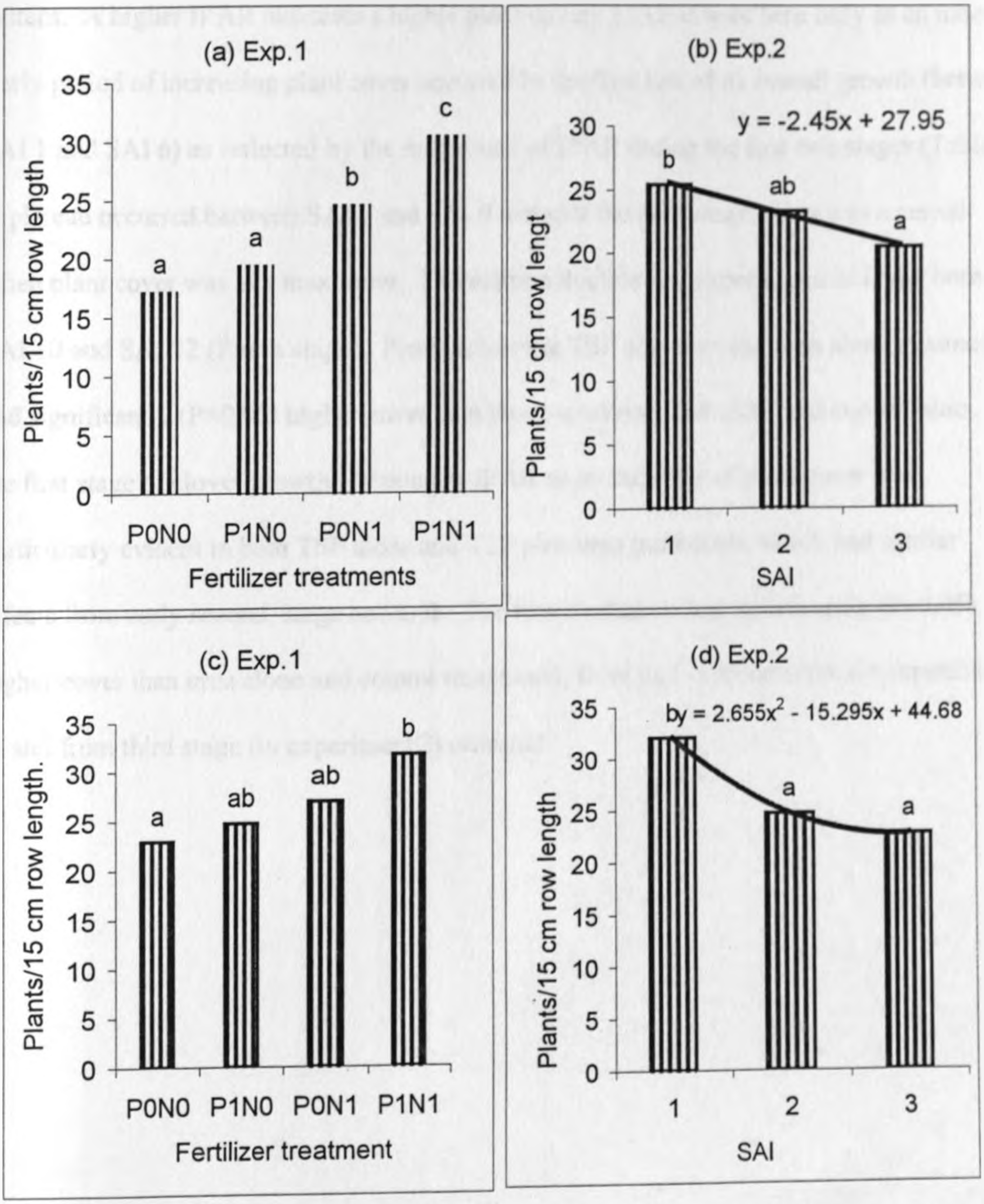


Fig. 2. Effects of fertilizer for exp.1 (a) and exp.2 (c), and SAI for exp.1 (b) and exp. 2 (d) on plant field establishment at Kabete, Kenya.

SAI =Sampling intervals.

P0N0 = control; P1N0 =TSP alone; P0N1 = urea alone; P1N1= TSP plus urea

4.4 Plant Cover [As Indicated by Intercepted Photosynthetically Active Radiation (IPAR)]

According to Fig. 3a and 3b, IPAR trend on the overall almost followed a sigmoid pattern. A higher IPAR indicates a higher plant cover. IPAR is used here only as an index. Early period of increasing plant cover occurred in the first half of its overall growth (between SAI 1 and SAI 6) as reflected by the magnitude of IPAR during the first two stages (Table 1). A plateau occurred between SAI 7 and SAI 9 towards the third stage. This was a period when plant cover was at a maximum. Thereafter a decline was experienced in IPAR between SAI 10 and SAI 12 (fourth stage). Plants receiving TSP plus urea and urea alone treatments had significantly (P=0.05) higher cover than those receiving TSP alone and control plots, in the first stage of clover growth. Maximum IPAR as an indicator of plant cover was particularly evident in both TSP alone and TSP plus urea treatments, which had similar effects from early second, stage onwards. The two treatments had significantly (P=0.05) higher cover than urea alone and control treatments, from mid - second stage (in experiment 1) and from third stage (in experiment 2) onwards.

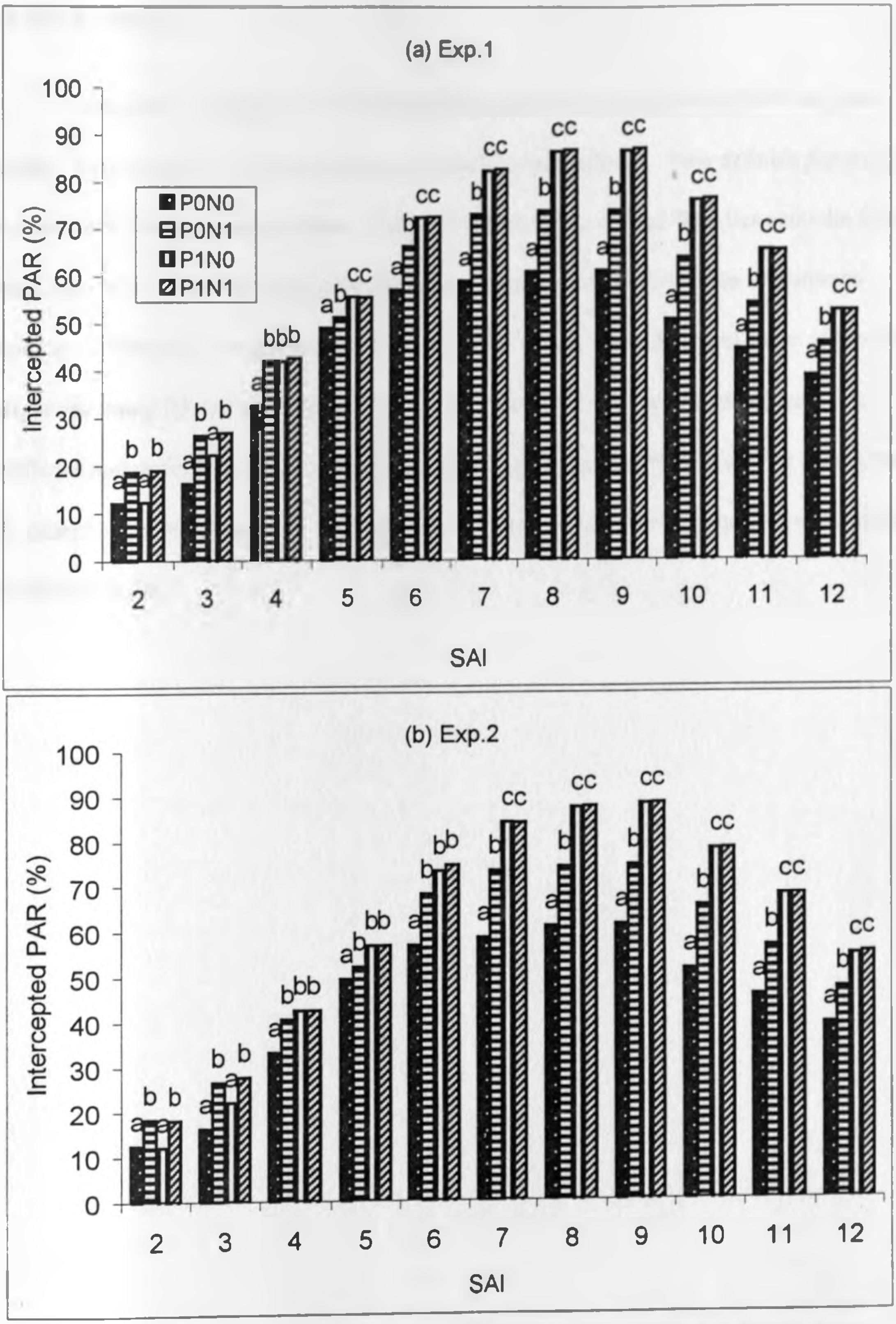


Fig. 3 : Photosynthetically Active Radiation (PAR) intercepted by the plant canopy in exp. 1(a) and exp.2 (b).

P0N0 = control; P0N1 = urea alone; P1N0 = TSP alone; P1N1= TSP plus urea

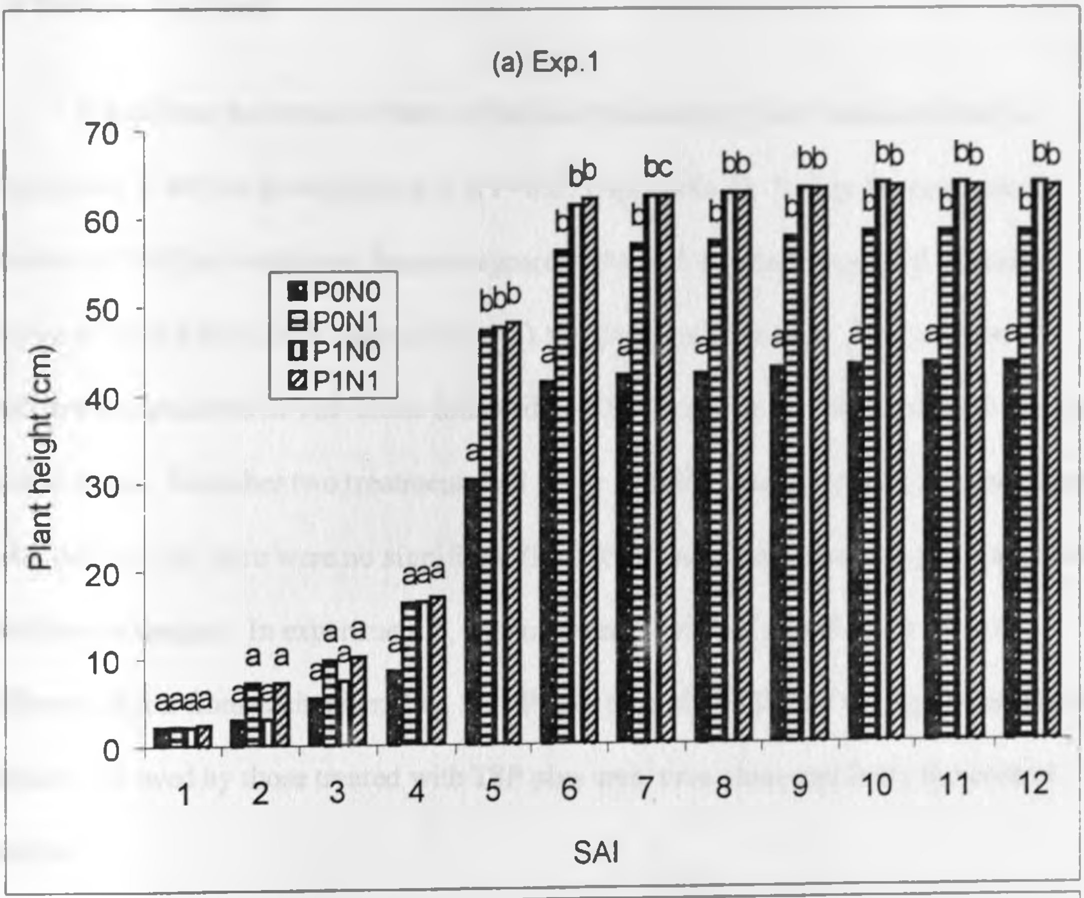
SAI = Sampling intervals.

Columns headed by the same letter are not significantly different at P=0.05 using LSD Test a each SAI.

4.5 Plant Height

There was a significant (P=0.05) interaction between fertilizer and SAI on plant height. This occurred in both experiments 1 and 2 (Appendix 3). Two definite patterns can be observed from this interaction in both experiments (Fig. 4a and 4b). Between the first stage and early second stage of growth (Table 1), there was no noticeable response to fertilizer, while height was generally below 20 cm. From the mid-second stage of growth, height exceeded 20 cm, while significant differences (P=0.05) were detected between fertilized and unfertilized plots. The control had significantly (P=0.05) shorter plants than all the other treatments from mid - second stage onwards. The other treatments were statistically (P=0.05) similar.

(a) Exp.1



(b) Exp.2

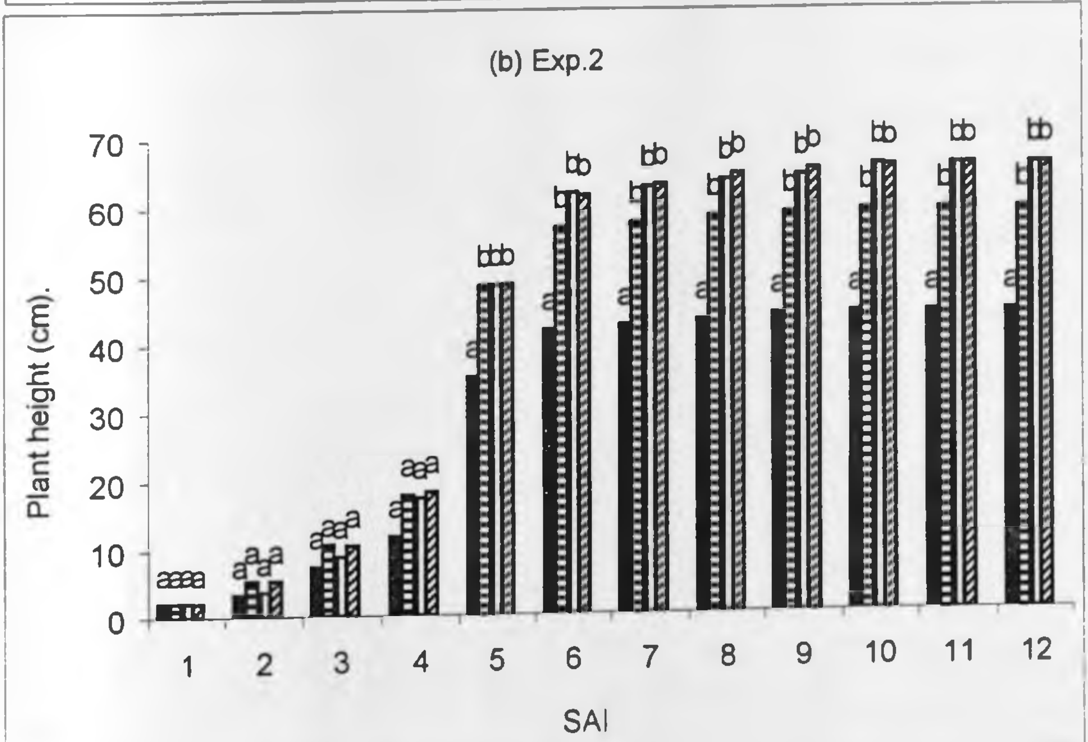
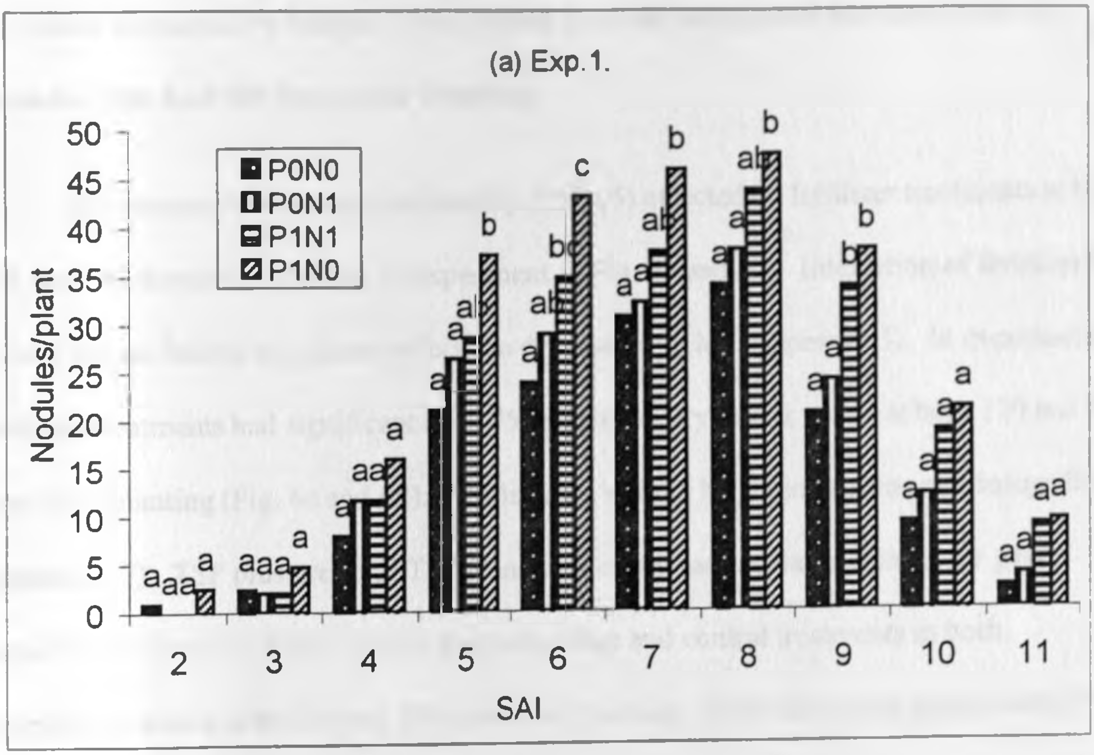
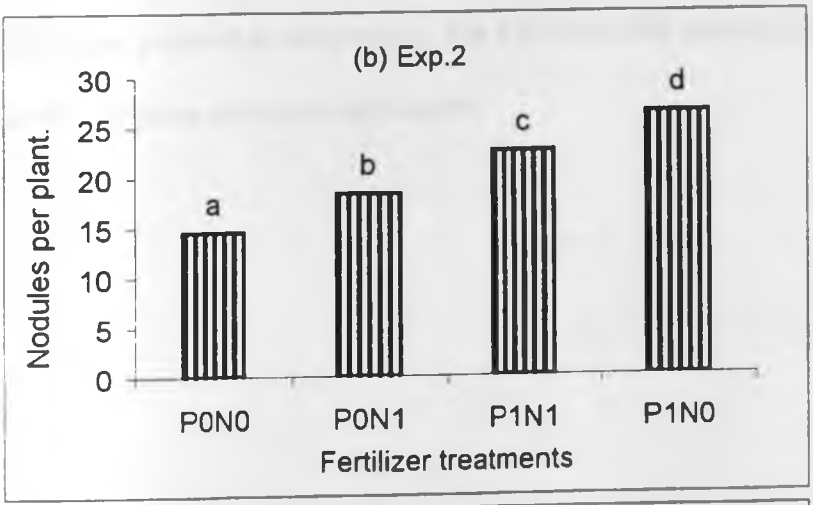


Fig. 4 Plant height (cm) for exp.1(a) and exp.2 (b)
Columns headed by the same letter are not significantly different at P=0.05 using LSD Test at each SAI.
P0N0 = control; P0N1 = urea alone; P1N0 = TSP alone; P1N1 = TSP plus urea
SAI =Sampling intervals.

4.6 Nodules Per Plant

Significant interaction effects of fertilizer treatment by SAI were detected in experiment 1, but not in experiment 2 at P=0.05 (Appendix 4). In Fig. 5a, response of nodules to fertilizer treatments became apparent at SAI 5 (second stage) and linearly increased until SAI 8 (third stage of growth) and declined thereafter. High nodule proliferation occurred in TSP alone followed by TSP plus urea treatment, particularly in the second stage. The other two treatments had fewer nodules as was apparent in experiment 1. After the SAI 10, there were no significant (P=0.05) differences in nodules per plant among fertilizer treatments. In experiment 2, fertilizer treatments had significantly (P=0.05) different effects from each other (Fig. 5b). Plants receiving TSP had the highest number of nodules followed by those treated with TSP plus urea, urea alone and lastly the control treatment.





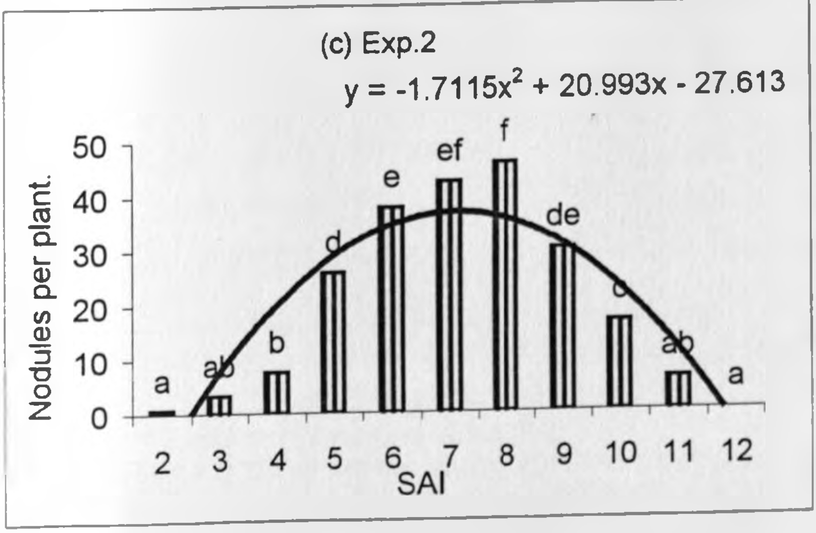


Fig.5: Nodules per plant for exp.1(a), and for exp. 2 as influenced by fertilizer (b), and SAI (c).

Columns headed by the same letter are not significantly different from each other at P = 0.05 using LSD Test at each SAI.
P0N0 = control;
P0N1 = urea alone;
P1N0 = TSP alone;
P1N1 = TSP plus urea.
SAI=Sampling interval

4.7 Above Ground Dry Matter Yield at Mid Harvest and End of Maturity Harvest Periods (120 And 180 Days after Planting)

Dry matter yields were significantly (P=0.05) affected by fertilizer treatments at both 120 and 180 days after planting in experiment 1 (Fig. 6a and 6b). Interaction of fertilizer by stubble height had no significant effects on dry matter yields (Appendix 5). In experiment 2, fertilizer treatments had significant (P=0.05) effects on dry matter yields at both 120 and 180 days after planting (Fig. 6c and 6d). Fertilizer by stubble height interaction was insignificant (Appendix 7). TSP plus urea and TSP alone treatments had similar effects. They gave significantly (P=0.05) higher yields than urea alone and control treatments in both experiments and at both 120 and 180 days after planting. Urea alone gave significantly (P= 0.05) higher yields than the control. The 120 days-after-planting harvest gave higher yields than the 180 days-after-planting harvest.

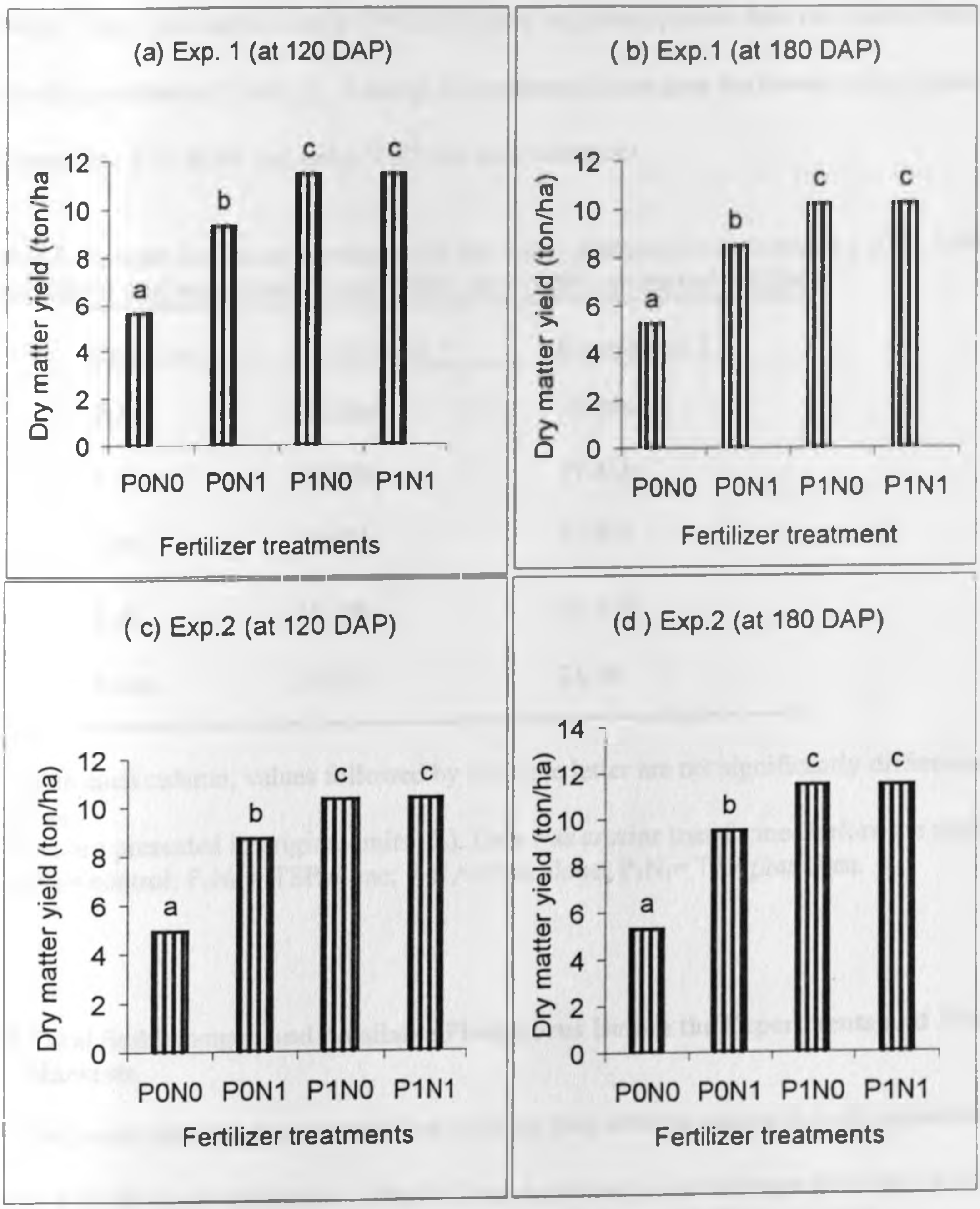


Fig. 6.Dry matter yield as influenced by fertilizers for exp.I at 120 days after planting (a) and at 180 days after planting (b),and for exp.2 at 120 days after planting (c) and at 180 days after planting (d).

Columns headed by the same letter are not significantly different at P = 0.05 using LSD Test.

P0N0 = control; P0N1 = urea alone; P1N0 = TSP alone; P1N1 = TSP plus urea.

DAP = Days after planting.

4.8 Percent Leaf Crude Protein

Generally, fertilizer treatments had significant (P=0.05) effects on percent leaf crude protein (Appendix 7). TSP alone, TSP plus urea and urea alone treatments had similar effects. They gave significantly (P=0.05) higher leaf crude protein than the control treatment in both experiments (Table 2). Among the treatments, urea gave the lowest crude protein, followed by TSP alone and lastly TSP plus urea treatment.

Table 2. Percent leaf crude protein at 180 days after planting for experiment 1 (Oct. 1999-April 2000) and experiment 2 (Jan. 2000 - July 2000) carried out at Kabete.

Fertilizer	Experiment 1	Experiment 2
P_0N_0	18.68a*	18.74a
P_1N_0	26.47b	27.41b
P_0N_1	26.43b	27.43b
P_1N_1	26.77b	27.55b
Mean	24.59	25.28

*Within each column, values followed by the same letter are not significantly different at $LSD_{0.05}$.
Values are presented in original units (%). Data was arcsine transformed before the analysis.
P_0N_0= control; P_1N_0 = TSP alone; P_0N_1= Urea alone; P_1N_1= TSP plus Urea.

4.9 Total Soil Nitrogen and Available Phosphorus Before the Experiments and After the Harvests

Total soil nitrogen was lower before planting than after harvesting in both experiments 1 and 2 with fertilizer application. The 0-15 cm depth had higher nitrogen than the 15-30 cm depth (Table 3).

Higher phosphorus levels were found in 0-15cm depth than in 15-30 cm depth in both experiments. Before planting, phosphorus levels were generally higher than after harvesting in control and urea alone treatments. The opposite was true in TSP alone and TSP plus urea treatments (Table 4).

For both phosphorus and nitrogen, no statistical analysis was done as each treatment was represented by one sample in each experiment.

Table 3. Percent total soil nitrogen before planting and after harvesting for experiment 1 (Oct. 1999-April 2000) and for experiment 2 (Jan. 2000-July 2000) carried out at Kabete.

	Depth (cm)			
	Experiment 1		Experiment 2	
	0-15cm	15-30cm	0-15cm	15-30cm
Before	0.28	0.26	0.29	0.26
After harvesting				
P_0N_0	0.29	0.26	0.29	0.26
P_0N_1	0.42	0.35	0.41	0.36
P_1N_1	0.91	0.86	0.92	0.86
P_1N_0	1.25	1.19	1.22	1.19

P_0N_0 = control; P_0N_1 = urea alone; P_1N_0 = TSP alone; P_1N_1 = TSP plus urea.

Table 4. Soil available phosphorus (ppm) before planting and after harvesting for experiment 1 (Oct. 1999-April 2000) and experiment 2 (Jan. 2000- July 2000) carried out at Kabete.

	Depth (cm)			
	Experiment 1		Experiment 2	
	0-15cm	15-30cm	0-15cm	15-30cm
Before planting	18.80	17.75	18.75	17.55
After harvesting				
Fertilizer				
P_0N_0	9.90	8.50	9.25	8.35
P_0N_1	6.10	4.50	6.05	4.35
P_1N_0	22.5	18.75	21.90	18.20
P_1N_1	31.25	26.25	30.75	25.75

P_0N_0 = control; P_1N_0 = TSP alone; P_0N_1= urea alone; P_1N_1= TSP plus urea

4.10 Correlation among Variables

First trial

Height was positively and significantly (P=0.05) correlated with cover (Table 5a). Distinct significant correlation was evident between percentage N (tissue) & DM in P treatment alone, between height & DM and between cover & DM in the compound treatment.

Height was positively and significantly (P=0.001) correlated to cover and establishment in urea treatment and not in the control (Table 5b). Cover was significantly correlated with establishment irrespective of fertilizer treatment

Dry matter and crude protein although positively and significantly (P=0.001) correlated, was unaffected by fertilizer

Second trial

Cover was positively and significantly (P=0.05) correlated to crude protein and number of nodules under P alone and not in the compound formulation (i.e. TSP + Urea). Establishment was significantly (P=0.001) and positively correlated to nodule number in the compound treatment.

Significant (P=0.001) correlation between height & cover and height & establishment were apparent irrespective of starter fertilizer (Table 5d). Significant (P=0.001) and positive correlation were found between cover and dry matter (in urea treatment), cover and establishment (irrespective of fertilizer treatment) and between nodules and crude protein in urea treatment.

Table 5(a). Correlation among variables for fertilizer treatments P_1N_0 and P_1N_1 in experiment 1 carried out at Kabete between Oct. 1999 and April 2000.

	Hgt.		Cov.		DM.		Esta.		Nods.		CP.	
	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1
Hgt.	1.00	1.00	.57ns	.99*	.81ns	.99*	.57ns	.66ns	-.15ns	-.61ns	-.80ns	.22ns
Cov.			1.00	1.00	.92ns	-1.00**	.64ns	.68ns	.90ns	.88ns	.63ns	.79ns
DM					1.00	1.00	.78ns	.68ns	.65ns	.58ns	1.00**	.92ns
Esta.							1.00	1.00	.91ns	.21ns	.79ns	.59ns
Nod									1.00	1.00	.46ns	.91ns
CP.											1.00	1.00

Pearson correlation. Sig. (2 tailed) * (P=0.05); ** (P=0.001); Ns = not significant
Hgt. = Plant height; Cov. = Plant cover; Nods. = Nodules/plant; Esta. = Field establishment; CP. = Crude protein; DM = Dry matter;
P_0N_0 = Control; P_0N_0 = urea alone; P_1N_0 = TSP alone; P_1N_1 = TSP plus urea

Table 5 (b). Correlation among variables for fertilizer treatments P_0N_0 and P_0N_1 in experiment 1 carried out at Kabete between Oct. 1999 and April 2000.

	Hgt.		Cov.		DM.		Esta.		Nods.		CP.	
	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1
Hgt	1.00	1.00	.98ns	1.00**	.98ns	.87ns	.98ns	1.00**	.90ns	.98ns	.19ns	.98ns
Cov			1.00	1.00	.91ns	.87ns	1.00**	1.00**	.96ns	.98ns	.80ns	.87ns
DM					1.00	1.00	.91ns	.77ns	.77ns	.84ns	1.00**	.91ns
Esta.							1.00	1.00	.97ns	.98ns	0.80ns	.87ns
Nods									1.00	1.00	.26ns	.76ns
CP.											1.00	1.00

Pearson correlation. Sig. (2 tailed) * (P=0.05); ** (P=0.001); Ns = not significant
Hgt. = Plant height; Cov. = Plant cover; Nods. = Nodules/plant; Esta. = Field establishment; CP. = Crude protein; DM = Dry matter;
P_0N_0 = Control; P0N0 = urea alone; P1N0 = TSP alone; P1N1 = TSP plus urea

Table 5 (c). Correlation among variables for fertilizer treatments P_1N_0 and P_1N_1 in experiment 2 carried out at Kabete between Jan. 2000 and July 2000.

	Hgt.		Cov.		DM.		Esta.		Nods.		CP.	
	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1	P_1N_0	P_1N_1
Hgt.	1.00	1.00	.60ns	.60ns	.84ns	.84ns	.95ns	.95ns	.95ns	.95ns	.40ns	.40ns
Cov.			1.00	1.00	.94ns	.94ns	.97ns	.93ns	.99*	.93ns	.99*	.90ns
DM					1.00	1.00	.87ns	.84ns	.77ns	.84ns	.90ns	.96ns
Esta.							1.00	1.00	.98ns	1.00**	.96ns	.66ns
Nods									1.00	1.00	.99ns	.86ns
CP.											1.00	1.00

Pearson correlation. Sig. (2 tailed) * ($P=0.05$); ** ($P=0.001$); Ns = not significant

Hgt. = Plant height; Cov. = Plant cover; Nods. = Nodules/plant; Esta. = Field establishment; CP. = Crude protein; DM = Dry matter; P_0N_0 = Control; P_0N_0 = urea alone; P_1N_0 = TSP alone; P_1N_1 = TSP plus urea

Table 5 (d). Correlation among variables for fertilizer treatments P_0N_0 and P_0N_1 in experiment 2 carried out at Kabete between Jan. 2000 and July 2000.

	Hgt		Cov.		DM.		Esta.		Nods.		CP.	
	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1	P_0N_0	P_0N_1
Hgt	1.00	1.00	1.00**	.92ns	.88ns	.59ns	1.00**	1.00**	.98ns	.93ns	.99ns	.93ns
Cov.			1.00	1.00	.88ns	1.00**	1.00**	.92ns	.98ns	.88ns	.99ns	.96ns
DM.					1.00	1.00	.88ns	89ns	.77ns	.54ns	.94ns	.94ns
Esta							1.00	1.00	.98ns	.93ns	.99ns	.93ns
Nods.									1.00	1.00	.95ns	1.00**
CP.											1.00	1.00

Pearson correlation. Sig. (2 tailed) * (P=0.05); ** (P=0.001); Ns = not significant

DM = Dry matter; Hgt. = Plant height; Cov. = Plant cover; Esta. = Filed establishment; Nods. = Nodules /plant; CP. = Crude protein.

P_0N_0 = control; P_0N_1 = urea alone; P_1N_0 = TSP alone; P_1N_1 = TSP plus urea.

CHAPTER FIVE: DISCUSSION

5.1 Phenological Stages

Four growth stages are evident in Mealton 5. They are best illustrated by Fig. 5c and represented by the equation $y = -1.7115x^2 + 20.993x - 27.613$ for nodule distribution per plant. They are described here as follows: First stage–early seedling stage or just simply the pre-45-day-old plants (SAI 1- SAI 3). This was a stage of slow growth. Slow growth could have been because leaves were few and small and so photosynthesis was slow. The roots were few and small and so the plant development was slow, as the rate of photoassimilate accumulation was slow. Second stage-active seedling growth stage or simply the pre-90-day-old plants (SAI 4 - SAI 6). This was characterized by a rapid increase in plant cover, height and nodules. This could have been because leaves were more and active in photosynthesis. The roots had developed rapidly enough to take up nutrients and water. This phase ended at around flowering time. Third stage-maturity stage or simply the pre-120-day-old plants (SAI 7- SAI 8). This was the time when growth was at maximum. This was around flowering and seed set. Cover and nodules had reached a maximum and increase in height was minimal from this stage onwards. Fourth stage-or simply post flowering stage (SAI 9-SAI 12). This was a decline phase. Cover and nodules declined while the plants fell over to form a mat. Leaf fall was evident while nodule senescence was rapid. This could have been because seeds were a stronger sink than leaves or nodules (Lawn and Brun, 1974a; Weil and Ohlrgge, 1972). The growth stages of Mealton 5 conformed to the growth cycle of annual crops as given by Herridge and Pate (1977).

5.2 Weather Conditions at the Experimental Site

As suggested in Fig. 1a, rainfall toward the end of the growth season (the senescent stage) did not lengthen the further growth of clover in the field. This could have been due to the fact that seeds were a stronger photoassimilate sink than leaves (Lawn and Brun, 1974a) and the growth centers had died. This could have been aggravated by leaf fall.

Longer rainfall duration at the early seedling stage enhanced establishment (Fig.1b) better than manual watering. This could mean that natural conditions as pertains to the season of planting, rainfall sufficiency and duration under rain-fed conditions might need to be critically evaluated in relation to the manual watering intervention. November month as a calendar time appears to be irrelevant in timing of planting. At Shola in Ethiopia, it was observed that African clovers planted during the Dry *Belg* season (March planting endowed with unusually extended rainy days) significantly out-yielded a crop planted in the Long rains (*Maher*) of June (Akundabweni, *et. al.*, 1991). In a separate study, Akundabweni (unpublished data) experienced a total crop-seed failure in a trial established on Mealton 5 planted in November, 1998 followed by heavy March rains in the following year at flowering/ podding. Inflorescences were destroyed and no seed was harvested.

Average air temperature during the study period was similar to the 10-year mean. Generally, temperatures are lower in May-August period compared to the other periods of the year at Kabete (Fig.1c). Kayinde, (2000), found that the early year planting of Mealton 5 in the warmer (Jan-June) favoured a higher seed production than the cooler mid-year July-December planting.

There could be agronomic implications about the rainfall cum temperature interaction(s) with respect to the best time of planting. This should be evaluated further as several scenarios pointed above indicate that the best time of planting of Mealton 5 is yet to be established.

5.3 Seed Germination and Field Establishment

Under conditions of Kabete, complete germination can occur in about 10 days after sowing scarified Mealton 5 clover seed (Akundabweni, pers. comm.). Moisture availability is essential for rapid germination. Great differences observed between seed germination (in test) and plant field establishment were mainly due to water stress in the field, which led to seedling mortality. Dry seeding, it appears, in the first 10 days is not recommended if maximum establishment is to be expected.

In this study, TSP had no significant effects on plant field establishment in experiment 1. Urea alone, however, had a significantly higher effect than TSP alone. TSP plus urea treatment resulted in significantly more plants than all the other treatments. In experiment 2, TSP plus urea resulted in significantly higher plant establishment. This conforms to the phosphorus and nitrogen effects of experiment 1. This suggests a degree of synergism when TSP and urea were applied together. The presence of nitrogen early in the first developmental stage may enhance photosynthesis at such early stages of plant growth, as biological nitrogen fixation might not have started. Due to small seed size, plants probably started photosynthesis early in the first stage due to small food reserves to survive, but needed nitrogen. Phosphorus would appear to have played a subsequent role possibly towards the second stage (SAI 4- SAI 6).

In symbiotic legumes, a starter nitrogen dose has been found to be essential for growth before the onset of nitrogen fixation (Eaglesham *et al.*, 1983; Sundstrom *et al.*, 1982; Gibson, 1981; Horst, 1986; Jutzi and Haque, 1984). Between infection and onset of nitrogen fixation, there exists a period of 21-35 days, during which the host does not benefit from the bacteria. During this period, the host depends on other sources of nitrogen for growth (FAO, 1984; Horst, 1986). In the present study, soil nitrogen was not high. Starter nitrogen dose might have been necessary for growth before BNF set in, because the first nodules were observed 28 days after planting.

The magnitude of seedling establishment is a precedent to the development of plant density (plants /unit area) when stand establishment has stabilized. Linear regression equation, thus, suggested that subsequent stand establishment was negatively related to the initial seedling establishment (Fig.2b and 2d). The self-thinning ability of Mealton 5 (in terms of stand development and establishment) is a progressive rather than retrogressive reduction.

Akundabweni (1984b) reported a similar trend in the early studies with *T. quartinianum*. Furthermore, he also found that seedling establishment increased with an increase in soil phosphorus, i.e., seedling losses decreased with an increase in soil phosphorus and perhaps the effect could have been greater had nitrogen been included. Mwania (1983) found that application of combined nitrogen and phosphorus significantly ($P = 0.05$) reduced the time to emergence of Irish potatoes. Present results on Mealton 5 appear to agree with potato findings. In the present study, application of each fertilizer alone enhanced establishment, but not as significantly as the combined fertilizer.

Decrease in number of plants over time in the first stage of Mealton 5 was a self-thinning phenomenon precedent to actual establishment by density (Akundabweni 1984b). Moisture had a very critical role in this actuation. When moisture was high and uniform, establishment of Mealton 5 was rapid and uniform.

5.4 Plant Cover

In the first stage of clover growth, urea alone and TSP plus urea had significantly ($P=0.05$) higher cover than TSP alone or control in both experiments. In the mid-second stage of growth, TSP alone or TSP plus urea had significantly ($P=0.05$) higher cover than the control or urea alone treatment. This pattern further confirms that nitrogen and phosphorus relayed their effects with each other in a complementary fashion.

The higher cover in TSP plus urea and urea alone in the early stages of plant growth was due to applied nitrogen. Nitrogen led to vigorous vegetative plant growth, which subsequently led to a phosphorus requirement.

Nitrogen generally leads to vigorous vegetative growth and a large leaf area (Tisdale *et al.*, 1993; Horst, 1986; Salisbury and Ross, 1986; Yoshida *et al.*, 1969). Akuja (1995) found that nitrogen application enhanced vegetative growth and leaf area of Mealton 5 during the early phases of the species growth. Particularly in the third stage, the high cover in TSP plus urea was possibly due to a continuous nitrogen supply first from applied nitrogen and later from biological nitrogen fixation. With phosphorus alone, the high plant cover was possibly due to nitrogen from biological nitrogen fixation pre-enhanced by TSP fertilizer.

In most annual legumes, BNF reaches a maximum at flowering and declines thereafter (Herridge and Pate, 1977; Vencatasamy and Peerally, 1981). With urea alone, because of the already inherently low phosphorus in the soil, nitrogen in itself did not enhance high plant cover development. Continued growth with urea however 'invoked in' the phosphorus demand for nodule development.

Between 3rd and 4th months i.e. initiation of flowering and seed set, (3rd stage), increase in plant cover was not high. This might have been due to competition for photoassimilates between leaves and seeds where seeds were a stronger sink as was reported by Lawn and Brun (1974a) in their study on soybeans. From 140 days after planting onwards, the low IPAR was due to leaf senescence. Leaf fall with advancing maturity could have been due to remobilization of nutrients from leaves to the seeds. Seeds normally assume a stronger sink leading to leaf death (Weil and Ohlrogge, 1972). At this same time, BNF had declined due to nodule senescence and starvation as most photoassimilates were directed to the seed sink. This shift was possibly further aggravated by leaf fall. Smith *et al.*,

(1990) reported that when phosphorus is remobilized from leaves and stem to reproductive tissues in late ontogeny in many crops, leaves senescence rapidly and will fall off.

5.5 Plant Height

In nearly sixty days (second stage) after planting, the fertilizers had not yet caused any detectable (significant) differences (P = 0.05) on plant height. By this stage, plant height development was slow and plants were generally shorter than 20 cm. However, a sharp increase began in the better part of the second stage and became steady.

TSP or TSP plus urea promoted height more than urea alone in the second stage. This suggests a possible role of phosphorus just after the first stage. This is of interest to note in terms of split fertilizer management. The question is whether it could be necessary to apply nitrogen at the time of planting and TSP later in the second stage, if this could enhance a better overall response. Although urea enhances shoot elongation (Klemm, 1966; Tisdale *et al.*, 1993; Horst, 1986) to the extent that starter doses might be a prudent consideration, it ought to be applied together with phosphorus.

5.6 Nodules Per Plant

In the first two thirds of the first stage nodules were few and still in the formative stage. TSP had apparently not fully been accessed yet, as roots were also few and small. As leaf area increased, more photoassimilates possibly became available and led to increase spread of root mass, which then accessed the TSP. It was important that nodulation is completed during the first stage in time for the plants to revert to biological nitrogen fixation before the second stage when seedling growth was to be more active than before.

Just after the end of the third stage, a reduction in number of nodules was possibly due to less photoassimilates being available to the nodules. This was possibly due to competition for photoassimilates between seeds and nodules where seeds were a stronger sink (Lawn and Brun, 1974a; Andreeva *et al.*, 1998). This might then have led to their reduction in nitrogen fixing capacity as most of them senesced due to starvation and age (Hudd *et al.*, 1980). Biological nitrogen fixation requires a lot of energy that is provided by the host plant (Ryle *et al.*, 1979; Pate and Herridge, 1978; Minchin and Pate, 1974). There is a close correlation between photosynthesis and BNF due to energy demands by BNF (Horst, 1986). It is, thus, possible that nodule atrophy signaled the end of third stage of growth, which must have been very brief possibly between 100 and 115 days after planting. In this study, TSP alone promoted the highest number of nodules, followed by TSP plus urea, urea and lastly the control. In TSP alone, available soil nutrients led to the development of leaf area that provided photoassimilates for nodule growth. Applied phosphorus alone enhanced the process of nodule growth and BNF. In TSP plus urea and for urea alone, the nitrogen applied at planting time led to vigorous plant growth and large leaf area. With time, the plants used it up. This might have led to an increase in nodulation. In TSP plus urea the number of nodules increased more than in urea alone due to the applied phosphorus in the former, which probably enhanced nodulation. Under zero fertilizer, the lower number of nodules was due to the unfertilized soils.

Studies have shown an increase in nodulation due to phosphorus application in symbiotic legumes (Akundabweni, 1984b; Jutzi and Haque, 1984, 1985; Dadson and Acquah, 1984; Smart, 1976; Andrew, 1976; Freire, 1977; Kahurananga and Tsehay, 1991; Mugwira *et al.*, 1997; Keya and Mukunya, 1979; Ssali and Keya, 1986).

Time required for nodulation and degree of nodulation are greatly affected by the presence of nitrogen, particularly nitrate nitrogen. Effects of nitrogen on nodulation depend on the rate of applied nitrogen or soil nitrogen level. High level of nitrogen inhibits root infection process by decreasing root hair formation and number of infection threads (Munns, 1968; Carroll and Gressholff, 1983) and by increasing the number of aborted infections (Munns, 1977) and nodule degeneration (Chui, 1985). High nitrogen levels generally inhibits nodulation and nitrogen fixation (Dart and Mercer, 1965; Ssali and Keya, 1984, 1986; Summerfield *et al.*, 1977; Sundstrom *et al.*, 1982; Trimble *et* al., 1987; Peck and MacDonald, 1984; Heichel et *al.*, 1979; Oghoghorie and Pate, 1971; Wagner and Zapata, 1982; Ham and Caldwell, 1978). When mineral nitrogen is dissipated from the root zone, the nitrogen fixing capacity of *Rhizobia* is resumed and the nodules can regrow (Becana and Sprent, 1987; Horst, 1986).

Low rates of nitrogen applied at planting time leads to development of a large leaf area, which provides necessary photoassimilates thus enhancing nodulation and BNF (Mahon and Child, 1979; Dart and Wildon, 1970; Sundstrom *et al.*, 1982; Minchin *et al.*, 1981; Gibson., 1974; Chesney, 1975; Jutzi and Haque, 1984; Eaglesham *et al.*, 1983; Robinson *et al.*, 1974). Production of nodules requires energy expenditure in terms of carbon and nitrogen before any benefit can accrue to the host (Sprent, 1984). This is a disadvantage to legumes growing without nitrogen and the problem is more acute in small seedlings (Sprent, 1983). For small-seeded plants like Mealton 5, the seed reserves are little and so they need starter nitrogen to provide nitrogen needed for nodulation and plant growth before BNF sets in. Relatively large-seeded species like *V. faba* can nodulate in the dark as seed reserves are alot (Sprent, 1984). Sprent and Raven (1985) estimated that nearly one third of seed nitrogen reserves in *P. vulgaris* might be required for nodule formation. Legumes use available soil nitrogen before nodulating and fixing nitrogen symbiotically (Stewart *et al.*, 1968; Heichel *et al.*, 1984a). The present study, therefore, suggests that the 27-kg N/ha level of urea on Kabete Nitisols was neither too high nor too low to negatively interfere with nodulation.

5.7 Dry Matter Yields And Percent Leaf Crude Protein

In previous studies, Akundabweni (1984b) targeted his first harvest at 90 days and thereafter at 120 days after planting based on visual performance of *T. quartinianum*. Based on the present study, maximum dry matter can be expected after the third stage (i.e. <125 days after planting). In the present study at Kabete, dry matter yields at 120 and 180 days after planting were significantly affected by fertilizer treatments in both experiments. The higher dry matter yields at 120 than at 180 days after planting was probablly due to leaf fall, occurring primarily in the fourth stage. Cutting at 120 days after planting (in the 3rd stage) produced no regrowth as was expected. The 5-cm stubble gave similar yields, as did the10-cm stubble. Application of TSP plus urea or TSP alone gave the best dry matter yields compared to either urea alone or the control, which suggests that use of urea alone on Mealton 5 should be avoided. Where soils are high in nitrogen, TSP, however, can be applied alone.

Fertilizer application increased percent leaf protein. Low leaf protein levels in the control were due to less nitrogen being available to the plants. Poor fertility soils can, thus, be expected to yield low protein content.

Nitrogen leads to an increase in dry matter yield and total nitrogen content of many crops, including forage plants and small grains (Tisdale *et al*., 1993; Hehl and Mengel, 1972; Horst, 1986; Olson and Kurtz, 1982). Dadson and Acquaah (1984) found that in soybean, a similar yield increase was obtained with mineral fertilizer supply in combination of either 90 kg P/0 kg N or 0 kg P/120 kg N per hectare. Studies on Lucerne have shown that increasing inorganic soil nitrogen level leads to an increase in herbage yield and nitrogen concentration (Cherney and Duxbury, 1994; Cherney *et al*., 1995; Sora, 1994). Ondicho (1991) reported an increase in leaf protein due to nitrogen application to cowpeas. Ssali and Keya (1984) found an increase in dry matter yield and leaf nitrogen in cowpeas and beans due to addition of nitrogen. Minchin *et al.*, (1981) found a significant ($P = 0.05$) increase in dry matter yield and tissue nitrogen in cowpea due to nitrogen application.

Application of phosphorus increased dry matter yield, leaf nitrogen and phosphorus level of runner beans (Kahuro, 1990). Gervais (1960) reported that phosphorus fertilizer significantly increased nitrogen concentration in clovers, but not in grasses. High phosphorus levels increased dry matter yield, nitrogen concentration and phosphorus uptake in field beans (Ssali and Keya, 1986), and increased nitrogen uptake in Lucerne (Rao, 1971). Reneau *et al.*, (1983) working on sorghum reported that phosphorus fertilizer increased nitrogen concentration in sorghum. Okalebo (1982) found that increasing phosphorus rate on bulrush millet led to an increase in grain nitrogen, straw nitrogen and phosphorus.

Application of phosphorus has been shown to increase dry matter yield, percent phosphorus and nitrogen of pasture legumes (Andrew *et al.*, 1969). Akundabweni (1984a) found that application of 30 kg P/ha to *T. quartinianum* on a phosphorus-deficient soil increased dry matter yield six times compared to the control. Nnadi *et al.* (1993) found that phosphorus application increased dry matter yield of African annual clovers, their nitrogen and phosphorus contents, and nitrogen and phosphorus use efficiencies. On tropical pasture legumes, Karachi (1979) found that high phosphorus rates increased dry matter yield, percent leaf nitrogen and total nitrogen content. Olsen *et al.* (1971) found that increasing phosphorus rates increased dry matter yield, root nitrogen and phosphorus contents of *M. sativa* and *D. intortum*. Phosphorus has been shown to increase dry matter yield of annual clovers (Haque and Lupwayi, 1998, 1999; Mugwira *et al.*, 1997; Haque and Mugwira, 1991; Kong *et al.*, 1993; Haque and Jutzi, 1984, 1985; Kahurananga, 1991; Kahurananga and Tsehay, 1991; Akundabweni, 1984a, 1984b).

Nitrogen has been observed to influence vegetative growth of French beans more when combined with phosphorus due to a continuous adequate supply of nitrogen from BNF

(Palaniyandi and Smith, 1979). Waithaka (1989) found that Di - ammonium phosphate (DAP) led to more vegetative growth than Calcium ammonium nitrate (CAN) in French beans, because it supplied phosphorus (required for root development and nodulation) and gave a starter nitrogen dose. Sheard (1980) found that application of 30 kg P/ha or 30 kg P/30 kg N per hectare resulted in similar dry matter yield in Lucerne (*M. sativa*) seedlings, five weeks after planting. Ssali and Keya (1986) found that application of combined phosphorus and nitrogen or phosphorus alone had significant ($P = 0.05$) and similar effects on dry matter yield of cowpeas, while nitrogen alone had negligible effects. Jutzi and Haque (1984) found significant ($P=0.05$) and similar yield increases in African annual clovers due to application of either 30 kg P/ha or 27 kg N/30 kg P per hectare. Panwar et *al.* (1977) found no significant effects of nitrogen on grain yield of blackgrams, but phosphorus application significantly increased grain yields. In the present study, combination of nitrogen and phosphorus was not advantageous over application of phosphorus alone as far as dry matter yields and protein content were concerned in Mealton 5 at Kabete Nitisols..

5.8 Total Soil Nitrogen and Available Phosphorus

Total soil nitrogen was lower before planting than after harvesting in both experiments. BNF possibly supplied enough nitrogen for plant growth and left the excess in the soil. The high residual nitrogen under TSP or TSP plus urea could have been due to higher number of nodules and hence higher rates of BNF. Lower residual nitrogen in the control was possibly due to lower rates of BNF. Ability of Mealton 5 to leave high amounts of soil nitrogen as a natural way of enhancing soil fertility was shown by Kayinde (2000). Mealton 5 has high root mass and high number of nodules (Wondafrash, 2000). Thus, the higher percent nitrogen content in the top 0-15 cm than in the lower 15-30 cm depth was possibly due to higher organic matter in the top 0-15 cm depth where, Mealton 5's roots mostly proliferate.

Phosphorus levels were higher before planting than after harvesting in control and urea alone treatments. This is because the plants used soil nitrogen. Lower soil residual levels after harvesting from urea alone compared to the control was possibly due to greater demand for phosphorus by the 'nitrogenized' plants. In TSP plus urea and TSP alone the higher residual phosphorus was due to phosphorus applied at planting time, all of which was not utilized by Mealton 5. Lower rates of phosphorus were previously shown to have residual effects (Akundabweni, 1984b; Nnadi *et al*., 1993; Haque and Lupwayi, 1998) after production of African annual clovers. In phosphorus-deficient soils, studies showed that phosphorus rates for maximum dry matter yield of African annual clovers range between 20 and 40 kg P/ha (Akundabweni, 1984b; Nnadi *et al*., 1993; Kahurananga, 1991).

The agronomic importance of this relates to the fodder crop- food crop integration in rotation cultivation.

5.9 Correlation among Variables

Positive and significant (P=0.001) correlation was found between dry matter yields and crude proteins in phosphorus treatment. This appears to suggest that nitrogen component of the treatment showed no effect. Fribourg and Johnson (1955), working on Lucerne, sweet clover, red and Ladino clover found such a significant (P=0.05) linear relationship (r = 0.98) between total dry matter yields and total nitrogen yields. Sora (1994) found that the amount of total nitrogen fixed by Lucerne closely followed the amount of dry matter yields at each growth stage. Tuohy *et al*. (1991) found that leaf nitrogen was closely related to leaf photosynthesis and, thus, dry matter yields.

Linear correlation between dry matter yields and plant field establishment was positive and coefficient of linear correlation (r) ranged from 0.68 to 0.91. Positive correlation was expected, because the plants that established contributed to dry matter yields. Again better establishment should be expected to be positively associated with better dry matter yields. Lack of a significant correlation could have been because as plant density increased, competition among plants might have reduced yield per plant. Finally, increase in dry matter yields due to increase in density will be less, i.e. the law of diminishing yield increment (Horst, 1986). Fewer plants of Mealton 5, in fact, eventually increase dry matter yields through branching and tillering, under ambient growth conditions (Akundaabweni,1984b).

Significant (P=0.001) linear correlation was observed between dry matter yields and plant cover with application of nitrogen. This was inconsistent with results of dry matter yields and crude proteins. Higher plant cover is a reflection of higher above ground biomass in Mealton 5. The most obvious feature of foliage canopies as related to production is the density of the foliage canopy. Ecologists have long made a practice of estimating percent cover and relating this to production. Less than full cover permits solar radiation to escape interception by phhotosynthetic apparatus (Williams and Loomis, 1969). Williams, *et al.* (1965a) found that when cover is scant, production is directly related to the fraction of light intercepted.

Linear correlation between plant cover and nodules, was positive and significant (P=0.05) with phosphorus application. Increase in nodules and, thus, BNF led to an increase in plant cover due to available nitrogen. This led to an increase in dry matter yields. The number of nodules reached a maximum at seed set in the third quarter and declined thereafter. Nodule senescence in studies elsewhere began at the end of reproductive phase (Andreeva *et al.*, 1998). Failure of regrowth in Mealton 5 was probably signaled by a decline in effective nodules at the end of reproductive phase, which coincides with the third growth stage.

Positive and significant (P=0.001) correlation was found between plant cover and plant establishment irrespective of fertilizer treatment. A higher number of established plants, as expected provided cover, which was enhanced by application of phosphorus and nitrogen. The higher the number of plants, the higher the leaf area index, light interception and thus higher productivity (William, 1969).

Positive significant (P=0.001) correlation was found between crude protein and number of nodules per plant with application of nitrogen. Naturally, effective nodulation leads to an increase in plant available nitrogen from BNF. Increase in number of nodules with subsequent increase in amount of nitrogen fixed, leads to more nitrogen being available to the plants. (Horst, 1986).

Height and cover were positively and significantly (P=0.05) correlated. During the growth of Mealton 5, the early seedling growth stage is essentially erect. Because of the active growth period, the stand tends to develop in a semi-decumbent fashion. At this time, open inter-row spaces become covered with a near surface canopy. This should account for the significant correlation.

5.10 General Conclusions and Recommendations

Mealton 5 clover was found to have four growth stages (phases), a lower one in the early stages (1st stage), an incremental (2nd stage), a plateuing (3rd stage) and a declining one (4th stage). Harvest at the 3rd stage should be targeted when dry matter yields are at the maximum because in the later stages there is loss of yield through leaf fall and possibly loss of quality.

This study has shown that for better establishment of Mealton 5, application of small doses of starter nitrogen is vital. Application of nitrogen and phosphorus is even better because it led to less seedling mortality than application of each fertilizer alone.

For greater cover development to serve as living mulch, application of nitrogen plus phosphorus or phosphorus alone gave the highest cover. This was probably because of high rates of BNF as enhanced by applied phosphorus resulting in more nitrogen being available to the plants.

Harvesting should be done at ground level, because high cuts leave alot of material and yet there was no regrowth under conditions of this study.

TSP plus urea and TSP alone gave similar increases in dry matter yields and crude proteins of Mealton 5 under the conditions of Kabete. They also increased soil nitrogen and phosphorus possibly due to enhanced nodulation.

Mealton 5 clover has further indicated that it could add nodule nitrogen to the soil and it is non-competitive in intensively cultivated cropping systems as it spares phosphorus for use by other food crops.

Plant establishment in the field was non-significantly (P=0.05) correlated to dry matter yields possibly because fewer plants increased their yields through branching and tillering.

Recommendations:

1) Application of either TSP or a compound fertilizer such as DAP to give 30 kg P/ha or 27 kg N/30 kg P/ha respectively could equally be employed as starter rates for Mealton 5 at Kabete.

2) Effects of moisture availability on regrowth of Mealton 5 after cutting should be investigated.

3) Possibility of regenerating this clover from cuttings should be investigated in a bid to extend its duration in the field.

4) Optimum levels of phosphorus and nitrogen to give maximum dry matter yields at different moisture regimes and soil conditions should be investigated.

5) Different methods of seed pre-treatment before planting should be investigated so as increase the speed and to have fast and uniform establishment of the plant stand.

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Appendix. 1 Analysis of Variance for plant field establishment

(A) For experiment 1(Oct. 1999-April 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	1056.68	528.34		
Fertilizer	3	3759.8	1253.27	58.1*	3.05
SAI	2	579.51	289.76	13.43*	3.44
Fertilizer x SAI	6	28.93	4.82	0.22^{ns}	2.55
Experimental error	22	474.49	21.57		
Sampling error	108	31.27	0.29		
Total	143	5930.66			

(B) For experiment 2 (Jan. 2000-July 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	2272.67	1136.335		
Fertilizer	3	1574.35	524.78	9.04*	3.05
SAI	2	2325.79	1162.9	20.03*	3.44
Fertilizer x SAI	6	238.2083	39.7	0.68^{ns}	2.55
Experimental error	22	1277.17	58.05		
Sampling error	108	27.75	0.26		
Total	143	7715.94			

SAI Sampling intervals.
* Significant at P = 0.05
ns Not significant

Appendix 2 Analysis of Variance for percent plant canopy cover (arcsine transformed values).

(A) For experiment 1(Oct. 1999-April 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	0.01	0.005		
Fertilizer	3	1.47	0.49	3402.78*	2.72
SAI	10	16.91	1.691	11743.05*	1.95
Fertilizer x SAI	30	0.21	0.007	48.6*	1.7
Experimental error	86	0.012	0.000144		
Sampling error	264	0.096	0.00036		
Total	395	18.71			

(B) For experiment 2 (Jan 2000-July 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	0.042	0.021		
Fertilizer	3	2.95	0.98	657.26*	2.72
SAI	10	20.75	2.075	1391.65*	1.95
Fertilizer x SAI	30	0.93	0.031	20.79*	1.7
Experimental	86	0.128	0.00149		
Sampling error	264	0.195	0.00074		
Total	395	25			

SAI Sampling intervals.
* Significant at P=0.05

Appendix. 3. Analysis of Variance for plant height (cm).

(A) For experiment 1 (Oct. 1999-April 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	87.55	43.78		
Fertilizer	3	10250.00	3416.7	116.65*	2.71
SAI	11	167750	15250	520.66*	1.9
Fertilizer x SAI	33	3453.13	104.64	3.57*	1.69
Experimental error	94	2753.22	29.29		
Sampling error	288	3913.00	13.59		
Total	431	188206.99			

(B) For experiment 2 (Oct. 1999- April 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	2095.32	1047.66		
Fertilizer	3	17041.01	5880.34	96.8*	2.71
SAI	11	213214.73	19383.16	319.06*	1.9
Fertilizer x SAI	33	7193.52	217.99	3.59*	1.69
Experimental error	94	5710.9	60.75		
Sampling error	288	3469.83	12.05		
Total	431	248725.31			

SAI Sampling intervals.
* Significant at P=0.05

Appendix. 4. Analysis of Variance for nodules per plant.

(A) For experiment 1(Oct. 1999-April 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	2153.34	1076.67		
Fertilizer	3	18080.39	6026.8	167.9*	2.72
SAI	9	77638.696	8626.52	240.36*	2.0
Fertilizer x SAI	27	4766.98	176.55	4.9*	1.6
Experimental error	78	2799.33	35.89		
Sampling error	240	881.33	3.67		
Total	359	106320.33			

(B) For experiment 2. (Jan. 2000-July 2000)

Source	DF	SS	MS	Fcal	Fc
Block	2	4362.591	2181.3		
Fertilizer	3	3713.172	1237.72	26.09*	2.72
SAI	10	148210.798	14821.08	312.38*	1.95
Fertilizer x SAI	30	1316.051	43.868	0.9^{ns}	1.6
Experimental error	86	4080.298	47.45		
Sampling error	264	390	1.477		
Total	395	162072.909			

SAI Sampling intervals.
* Significant at P=0.05
ns Not significant

Appendix.5. Analysis of Variance For Dry Matter Yields (Kg/Ha) For Exp. 1(Oct 1999-April 2000)

(A) At 120, DAP.

Source	DF	SS	MS	Fcal	Fc
Block	2	8.468E+04	4.234E+04		
Fertilizer	3	1.493E+08	4.977E+07	191.94*	4.76
Error a	6	1.556E+06	2.593E+05		
Stubble height	1	7.413E+05	7.413E+05	4.83^{ns}	5.32
Fert. x Stubble height	3	5.250E+01	1.750E+01	0.00^{ns}	4.07
Error b	8	1.227E+06	1.534E+05		
Total	23	1.529E+08			

(B) At 180, DAP.

Source	DF	SS	MS	Fcal	Fc
Block	2	3.667E+06	1.834E+06		
Fertilizer	3	1.156E+08	3.854E+07	500.19*	4.76
Error a	6	4.623E+05	7.705E+04		
Stubble height	1	7.455E+05	7.455E+05	1.94^{ns}	5.32
Fert. x Stubble height	3	7.500E+00	2.500E+00	0.00^{ns}	4.07
Error b	8	3.073E+06	3.841E+05		
Total	23	1.236E+08			

Fert. Fertilizer
* Significant at P=0.05
ns Not significant

Appendix .6.Analysis of Variance for dry matter yields (kg/ha) in Exp. 2 (Jan.2000-July 2000)

(A) At 120, DAP.

Source	DF	SS	MS	Fcal	Fc
Block	2	3.430E+06	1.715E+06		
Fertilizer	3	1.616E+08	5.386E+07	57.92*	4.76
Error a	6	5.580E+06	9.301E+05		
Stubble height	1	7.459E+05	7.459E+05	0.86^{ns}	5.32
Fert. x Stubble height	3	9.413E+01	3.138E+01	0.00^{ns}	4.07
Error b	8	6.899E+06	8.623E+05		
Total	23	1.782E+08			

(B) At 180, DAP.

Source	DF	SS	MS	Fcal	Fc
Block	2	1.094E+06	5.471E+05		
Fertilizer	3	1.251E+08	4.170E+07	53.18*	4.76
Error a	6	4.705E+06	7.841E+05		
Stubble height	1	7.477E+05	7.477E+05	1.16^{ns}	6.32
Fert. x Stubble height	3	3.000E+00	1.000E+00	0.00^{ns}	4.07
Error b	8	5.164E+06	6.455E+05		
Total	23	1.368E+08			

Fert. Fertilizer
* Significant at P=0.05
ns Not significant

Appendix. 7. Analysis of Variance for percent leaf crude proteins (transformed values)

(A) For experiment 1(Oct. 1999- April 2000)

Source	DF	SS	MS	Fcal	Fc
Fertilizer	3	0.01366	0.00455547	199.23*	4.07
Error	8	0.000183	0.00002286		
Total	11	0.01385			

(B) For experiment 2 (Jan.-2000- April 2000)

Source	DF	SS	MS	Fcal	Fc
Fertilizer	3	0.0169	0.00564	6189045*	4.07
Error	8	0.0000073	0.000000912		
Total	11	0.0167			

* Significant at P=0.05