

EVALUATION OF MINJINGU PHOSPHATE ROCK AS A SOURCE OF  
PHOSPHORUS FOR GRAPEVINE PRODUCTION IN DODOMA DISTRICT  
TANZANIA



BY

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**ABSTRACT**

Experiments were conducted to assess the P status of selected soils of Dodoma district, Tanzania and the response of grapevine to P application. The experimental sites were Msalato A, Msalato-Manispaa and Veyula-Makutupora. The studies included (i) the initial fertility characterization of the experimental soils (ii) an incubation study and (iii) a field trial which compared MPR and TSP as sources of P.

Results from the characterization study showed that fertility status decreased with increasing distance from the tree trunk congruent to the location of the fertilizer band.

In the incubation experiment, solubility of MPR was found to increase steadily with time until equilibrium was reached at about 45 days. At this time 52% of the applied MPR, equivalent to 260 mg P/kg had dissolved. Soil samples incubated with TSP at this time released 64% of soluble P. Calcium and Phosphorus sinks were demonstrated as important parameters which influenced P dissolution in the test soils.

In the field trial, both TSP and MPR application increased grape yield significantly over the control with TSP giving higher yield than MPR. The relative agronomic effectiveness (RAE) value for MPR averaged 67%,


suggesting that TSP had a higher fertilizer value. The study further demonstrated that P rates above 168 kg P/ha decreased grape yields at Veyula-Makutupora site while at Msalato A and Msalato-Manispaa sites yields continued to increase.

From these findings, it was concluded that:

- (1) in addition to N, P application was needed in order to optimize grape yield in Dodoma district and a tentative rate of 168 kg P/ha is recommended.
- (2) Minjingu PR was found to be a promising substitute for TSP but assessment of residual effects should be made before a definite recommendation can be made.
- (3) further research should be conducted to increase P use efficiency.

**DECLARATION**

I, GEORGE M. R. BUDOTELA, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted in any other University for a degree award.

Date : 25/10/95.....Signature: 

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1 Mrs. Bukuku; Msalato-A site

2 Mr. Haule;Veyula-Makutupora site

3 Mr. Kalale;Msalato-Manispaa site

My family, especially my aging parents and children: Raphael, Peter and Felista, missed me for the period I was studying. I hope that their sacrifice was worth while. My wife, Regina, deserves special thanks for her constant encouragement and taking over my family responsibilities which I could not perform on account of my engagements at the University. I deeply appreciate her generosity.

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**DEDICATION**

This dissertation is dedicated to my beloved parents who took trouble of taking me to school.

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**CHAPTER ONE****INTRODUCTION**

Phosphorus is an essential input for balanced fertilization and often a major constraint to successful crop production (Jaggi, 1986; Mokwunye et al., 1986). It is a major limiting nutrient in highly weathered soils such as Ultisols and Oxisols (Sanchez, 1976).

Nitrogen (N), phosphorus (P) and potassium (K) are critical plant nutrients each of which has a specific action on the growth and bearing capacity of the vine (Pongracz, 1978). Nitrogen is known to promote initiation and differentiation of inflorescence primordia in grape (Alleweldt, 1964; Camp, 1964 ; Shivasankara, 1967). Similar effects have also been reported with P (Fleming, 1962; Kobayashi, 1960) and K (Archibald, 1956; Larsen, 1963). Specifically P promotes the development of grapes and better setting of berries and neutralises the harmful effects of excessive nitrogen dressings and promotes better ripening of the grapes and wood (Perold, 1927). Phosphorus also increases the phosphoric acid content of the must, which greatly favours alcoholic fermentation. Thus it raises the quality of the grapes and wine.

Grapes in Dodoma Capital City district occupy about 1000 ha. The variety Makutupora local is the most widely

planted due to its attractive size, moderate quality and dependable performance. Grape is the number one cash crop in the region. Soils in the area are characterised by low organic matter, nitrogen, CEC and available P but adequate K levels (Magogo et al., 1980). Grapes have a high nutrient demand but high yields can be obtained with adequate fertilization. Dasaradhi and Afzalunnissa (1977) estimated that a ten tonne crop of grapes removes 30kg of N, 20kg of  $P_2O_5$  and 50kg of  $K_2O$  per acre. The average yield of grapes in Dodoma region is about 2tonnes/ha however yields of up to 8tonnes/ha have been reported at the Viticultural Research and Training Centre, Makutupora (Detry, 1986; Unpublished report).

Fertilizer requirements of the vine in the study area have not yet been determined experimentally. Elaborate fertilizer trials on grapes, however, are now in progress at the Viticultural Research and Training Centre-Makutupora, but no definite fertilizer recommendations have so far been made. The current recommendation is to apply 20kg of kraal manure to each vine. The amount of nutrients supplied by manure is not known. In addition we suspect that manure may not supply adequate nutrients especially P. Further more there is an interest to evaluate alternative source of P in efforts to reduce costs of commercial fertilizers. Minjingu phosphate rock has shown promising results with annual crops (Anderson,

planted due to its attractive size, moderate quality and dependable performance. Grape is the number one cash crop in the region. Soils in the area are characterised by low organic matter, nitrogen, CEC and available P but adequate K levels (Magogo et al., 1980). Grapes have a high nutrient demand but high yields can be obtained with adequate fertilization. Dasaradhi and Afzalunnissa (1977) estimated that a ten tonne crop of grapes removes 30kg of N, 20kg of  $P_2O_5$  and 50kg of  $K_2O$  per acre. The average yield of grapes in Dodoma region is about 2tonnes/ha however yields of up to 8tonnes/ha have been reported at the Viticultural Research and Training Centre, Makutupora (Detry, 1986; Unpublished report).

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1970; Semoka *et al.*, 1992) but has not been tested on grapes. Thus to complement efforts of the Viticultural Research and Training Centre in the development of fertilizer recommendations for grape production, the present studies were initiated with the following objectives;

- (i) To establish the P fertility status of the selected vineyards in Dodoma Capital City district.
- (ii) To determine the effects of P application on grape yield.
- (iii) To compare the effectiveness of Minjingu phosphate rock with triple superphosphate in supplying P to grapevines.

## CHAPTER TWO

## LITERATURE REVIEW

The direct application of PR as source of phosphorus (P) in low pH soils has been widely reported as a possible alternative to the more expensive industrial phosphate fertilizers ( Hammond, 1977; Fenster and Leon , 1978; Khasawneh and Doll , 1978 ; Peaslee et al., 1962 ; Mnkeni et al., 1991; Jaggi, 1986 ). Numerous studies have been conducted to assess the factors influencing the dissolution of phosphate rocks (Khasawneh and Doll , 1978 ; Marwaha and Kanwar , 1978 ; MacClellan and Lehr , 1969 ; Robinson and Syers , 1990 ; Robinson and Syers , 1991 ). Generally they all established the following as factors affecting the effectiveness of PRs for direct application:

- (i) Reactivity of PR.
- (ii) Soil factors particularly pH , P and  
Ca levels and
- (iii) Plant factors .

### 2.1 Reactivity of PR

Phosphate rocks vary widely in their reactivity and subsequent agronomic value (Lehr and McClellan , 1972). Phosphates are found in all the three types of rocks namely Igneous, Metamorphic and Sedimentary, but in most

cases only sedimentary phosphates have proved beneficial for direct application. Igneous and metamorphic rocks are coarsely crystalline and do not possess internal surfaces as a result they are unreactive and nearly inert for direct application (Khasawneh and Doll , 1978). In contrast, sedimentary PRs consist of fairly open, loosely consolidated aggregates of microcrystals with relatively large specific surface area making them more reactive. Further more, it has been demonstrated that reactivity is a function of the degree of substitution of  $\text{CO}_3^{2-}$  for  $\text{PO}_4^{3-}$  in the apatite structure. Greater substitution results in higher reactivity (Khasawneh and Doll, 1978 ; Marwaha and Kanwar, 1981). Apparently, substitution of  $\text{CO}_3^{2-}$  for  $\text{PO}_4^{3-}$  decreases the crystal size (McClellan and Lehr, 1969) and increases the specific surface of the apatite aggregates.

## **2.2 Soil factors affecting PR dissolution**

### **2.2.1 Soil pH**

Several Workers (Peaslee et al., 1962; Fenster and Leon, 1978 ; Khasawneh and Doll, 1978 ; Joos and Black, 1950;) have indicated that agronomic effectiveness of PR is higher in acid soils than in neutral or alkaline soils. This occurs since as concentration of  $\text{H}^+$  ions increases, the solubility of PR also increases.

### 2.2.2 Soil calcium

Soils rich in Ca ions or free CaCO<sub>3</sub> have been found to decrease PR solubility (Khasawneh and Doll, 1978). Low Ca level means that the soil has additional capacity to adsorb Ca released during PR dissolution.

Robinson and Syers (1990) singled out a sink for Ca as the most important factor influencing the dissolution of Gafsa PR. Several workers (Graham, 1955; Chien, 1978; Khasawneh and Doll, 1978; Wilson and Ellis, 1984; Mackay et al., 1986) as quoted by Robinson and Syers (1990) have indicated that solution Ca concentration is an important factor controlling the dissolution of PR in soils.

### 2.2.3 Soil phosphorus

A sink for H<sub>2</sub>PO<sub>4</sub><sup>-</sup> similarly favours PR dissolution (Khasawneh and Doll, 1978). As an effective fertilizer, PR is limited to soils that are severely to moderately deficient in P, but it has little or no value in soils of medium to high P status (Amberger, 1978).

## 2.3 Plant factors affecting PR dissolution

Several workers (Cook, 1935; Fried and Mckenzie, 1949; Murdock and Seay, 1955; Khasawneh and Doll, 1978) have demonstrated that crops vary greatly in their ability to utilize P from PR. Generally, differences among crops are thought to be related to their demand patterns for

both Ca and P, and the way these demand patterns for Ca and P alter the composition of the soil solution at the root-soil interface. The extent of the root system is also important in P nutrition (Khasawneh and Copeland, 1973; Newman and Andrew, 1973). Roger et al. (1953) grouped crops into two classes: those which were efficient users of PR which included lupins, buckwheat, clover, mustard, swisschard, rape and cabbage and inefficient users of PR such as cotton, cowpeas and most cereals.

#### **2.4 Organic Matter**

The effect of incorporating organic matter on the dissolution of PR in the soil has been reported by many workers (eg. Mandal, 1973; Mathur, 1979; Ikerra et al., 1994). Ikerra et al. (1994) working with an Ultisol reported release of 58mg P per kg soil when Minjingu PR was combined with compost; 74mg P per kg soil when Minjingu PR was combined with farmyard manure and 45mg P per kg soil when Minjingu PR was applied alone after 60 days of incubation. However, the P contribution of the organic materials was not determined. In agreement with the above finding, Chakraborty (1982) also reported increased citrate extractable P in all plots receiving Purulia PR in combination with farmyard manure (FYM). It has generally been established that aliphatic organic acids, phenols, carboxylic acids, amino acids, complex

humic and fulvic acids and mineral acid ions are produced during the decomposition of organic matter in composts. These acids, together with the carbonic acids in the soil resulting from metabolic wastes of plant roots and microorganisms help in the dissolution of PR (Jaggi, 1986). Similarly, Alexander (1977) reported that PR solubilization is enhanced by the organic acids produced during the microbial decomposition processes in soils. Dalton et al. (1952) reported that the addition of fresh, dried plant residues resulted in the release of more P from PR, as a result of the decomposition of the fresh residues.

## **2.5 Other factors affecting PR dissolution**

Chemical composition, particle size, rate of addition, time of application and method of application have been shown to influence the PR dissolution (Patnaik et al., 1974; Marwaha et al., 1981; Mandal and Khan, 1982; Khasawneh and Doll, 1978; Motsara and Datta, 1971; Khasawneh and Sample, 1978).

### **2.5.1 Particle size**

Several workers have documented the effect of particle size on the dissolution of PR (eg. Hammond, 1978; Chien, 1978; Branes and Kamprath, 1975; among others). Hammond (1978) reported increased maize dry matter yield

as the size of ground North Carolina PR decreased from 0.15 to 0.075mm. Chien (1978), working with various PRs also reported increased P availability with decreased size of PR and increased reaction time. Similarly, Branes and Kamprath (1975), reported increased P availability with increased fineness of grinding, but grinding to a fineness of 0.15mm gave no further advantage.

#### **2.5.2 Rate of application**

Khasawneh and Sample (1978), varying the application rates of various PRs from 150 to 1800 mg per pot observed increases in dry matter yield of maize at six weeks as rates of application increased. Similar results were reported by Marwaha et al. (1981) working with maize and wheat. They observed that maize and wheat grain yields increased significantly with higher rates of Mussorie PR. However, contradicting results were reported by Motsara and Datta (1971). These workers observed no increase in the grain yield of rice as the rates of Mussorie PR were increased from 35.0 to 104.8 kg per ha.

#### **2.5.3 Time of application**

Agronomic response to PR fertilizer has been shown also to depend on the time of application. Patnaik et al. (1974), applying Mussorie PR to rice as a test crop observed increased grain yield as a result of advancing

the time of application by 30 days. Marwaha *et al.* (1981), working with Mussorie PR, also reported similar results. Mandal and Khan (1972), attributed the beneficial effects of PR application a few days before sowing to the slow but continuous solubilization of PR by soil solvents.

#### 2.5.4 Methods of application

Deep PR fertilizer placement to the zone where finest feeding-roots are situated has been reported to be of agricultural importance. Ensminger *et al.* (1967) reported higher yields where PR was broadcasted and thoroughly mixed into the soil than when banded. Khasawneh and Doll (1978), also advocated that PR placement should ensure thorough mixing with the soil in the rooting zone.

#### 2.6 Previous research work

Varying degree of success have been obtained with PR, both in field and pot experiments, depending on the prevailing conditions (eg. Hammond, 1978; Fenster and Leon, 1978; Khasawneh and Doll, 1978; Peaslee *et al.*, 1962; Mnkeni *et al.* 1991). Miranda *et al.* (1970) (as quoted by Fenster and Leon, 1978) tested three PRs using corn and found them to give yield increases ranging from 37% to 71% of that obtained with ordinary superphosphate. Fenster and Leon (1978) further quoted results of studies carried out by North Carolina State University and Cornell

University in Brazil from 1973-1975 comparing various PRs and single superphosphate (SSP) on pastures. The PRs used were Gafsa from Morocco, North Carolina from USA (both rated to be of high reactivity) and Araxa from Brazil, a PR of low reactivity. Initially the more reactive rocks were as effective as SSP. The Brazilian PR was ineffective initially but after two years P availability from this rock increased and yield was comparable to the other P carriers. Sanchez, (1976) showed that Gafsa, Florida, North Carolina and Fosbayovar (Peru) PRs were comparable to SSP in increasing yields of *Panicum maximum*.

Rice grown in acid soils has also shown good responses to PR application. Jaggi (1986) quoted results of experiments conducted on three acid soils from widely varying locations reported by the Nuclear Research Laboratory of the Indian Agriculture Research Institute in which phosphate rock was found to be as effective as or better than superphosphate in increasing paddy yield. Similarly, in trials conducted on Ultisols and their intergrades in Bihar, PR gave slightly higher yields than SSP for paddy, maize and groundnuts; comparable yields for gram and slightly lower yield for wheat (Mathur, 1979). Hardjono, (1988) working with seven rock phosphate sources observed them to be as effective as the standard phosphate fertilizer (TSP) in promoting oil palm growth and P uptake.

Cassanova *et al.* (1993), evaluating various sources of rock phosphate and basic slag on soil chemical properties and growth of *Brachiaria decumbens*, recommended use of Monte Fresco rock phosphate for permanent crops and forests with P requirements distributed over longer periods of time. Similarly, Lopes *et al.* (1991), using natural and modified phosphate rocks on annual, perennial and forest crops in Brazil concluded that: (i) the response of annual crops to phosphate fertilizer is proportional to the percentage of soluble  $P_2O_5$  in relation to the total  $P_2O_5$ , (ii) Brazilian phosphate rock present low solubility and low agronomic efficiency for annual crops, (iii) partially acidulated phosphate rocks can be adequate for pasture and perennial crops.

Considerable research has been conducted on vineyard fertilization in foreign countries using water-soluble phosphate fertilizers (Skinner and Matthew, 1989; Balo *et al.*, 1988; Conradie and Saayman, 1989; Nijjar, 1977; Srinivasan and Muthukrishnan, 1977), but information on phosphate rock for direct application in vineyards and/or perennial fruit trees is very limited. Skinner and Matthew (1989), working with 2-year old potted vines, *Vitis vinifera* L. (cv. carignane) under phosphorus-limited conditions for three growing seasons evaluated the effect of P status on growth and reproductive development of vine by withholding P at bloom and veraison phenological

stages. The authors reported decreased dry matter production, numbers of clusters/shoot and flowers/cluster to vines which received no P together with all treatments which had P withheld than vines which received P for the full season. Balo et al. (1988) tested three levels of P (9, 18, and 36 kg P/ha) and reported fruit yield and quality (as measured by fruit sugar content and sugar/acid ratio) increases over the control with increasing rates of P application. Similarly, Conradie and Saayman (1989), working with Chenin blanc vines on a sand loam soil which had 1.1% O M, 12.7 mg P/kg and 30 mg K/kg initially, tested three levels of N (16, 56 and 96 kg/ha), P (0, 9 and 18 kg/ha) and K (0, 45 and 90 kg/ha) and reported P fertilization to have a positive effect on yield and shoot growth. Likewise Nijjar (1977), working with 5-year old vines cv. Anab-e-Shahi tested three levels of P viz; 0.5, 1.0, and 1.5 kg P<sub>2</sub>O<sub>5</sub>/vine and reported grape yield and shoot growth increases with increased P application rates. Nijjar (1977), further quoted similar results by other workers (Nijjar and Ram, 1969; Nijjar and Chand, 1969 and Nijjar et al., 1971).

## **2.7 Fertilizer requirements of vines**

Like all other green plants with a root-system, the vine obtains its nourishments from the soil. Most soils contain all the food ingredients in larger quantities than

are required by vines, with the exception of nitrogen, phosphorus and potassium (Perold, 1927). A vineyard with an annual maximum production of 15,000 kg grapes, 3,200 kg wood (the weights for wood and leaves expressed on oven dry basis), and 2,900 kg leaves per hectare, annually removes out of the soil about 100 kg  $K_2O$ , 80 kg N and 30 kg  $P_2O_5$  per hectare (Perold, 1927). Hence, it is a sound policy to return to the soil what is removed by the crop if grape yields are to be sustained at desirable levels that will meet the demand of increasing population (Fongracz, 1978).

## **2.8 Concentrations of different nutrients in grapevines**

Balo et al. (1988) in Hungary established optimum leaf levels of P and K in grapes at bloom stage to be 0.22% and 1.2%, respectively and the optimum N/K ratio to be between 1.9 and 2.4. Conradie and Saayman (1989), in South Africa, working with Chenin blanc vines established P and K deficiency levels at veraison stage to be 0.08% and 1%, respectively. Christensen et al. (1978), in California reported P and K critical petiole levels at bloom stage to be over 0.15% and 1.5%, respectively. Similarly, Cook (1966), under Californian conditions reported P critical petiole level at bloom time to be 0.26%. Larsen (1955) in Michigan reported N and K critical petiole levels at bloom stage to be over 0.8% and 2%, respectively

**CHAPTER THREE****MATERIALS AND METHODS**

Field and incubation experiments were conducted to evaluate Minjingu PR as a source of P for grape production and to investigate the dissolution of the P sources in the experimental soils.

**3.1 Experimental sites**

The locations chosen for the experiments were Msalato A situated at 6° 04' 22.85" S and 35° 44' 55.8" E, Msalato-Manispaa situated at 6° 0.2' 58.1" S and 35° 45' 27" E and Veyula Makutupora situated at 6° 0.2' 20" S and 35° 45' 23.5" E, all of them at an altitude of approximately 1140 masl. The sites will be designated by these names hereafter. The three sites were selected so as to provide a range of pH, available P status, exchangeable cation contents and microclimatic conditions. At each site grapevines (*Vitis vinifera* L.) cultivar Makutupora local trained on cordon system, had been growing for ten years. The vines were grown in trenches of 30 cm width, 90 cm deep and 63 m in length. These trenches ensured the establishment of deep and well distributed root systems necessary for effective uptake of plant nutrients.

The undisturbed land between two trenches was 170 cm in width. Into each trench 5 tonnes of farmyard manure were mixed with soil. Farmyard manure incorporation is very vital under Dodoma climate (very dry and hot. Appendix 3) and soil conditions (very poor in organic matter. Table 1). This initial manuring is aimed at supplying plant nutrients and improving soil structure, and water holding capacity of the soils. In unirrigated vineyards of Dodoma, the only water available to the vines through most of the growing season is that which is stored in the soil from the little rains received. For the previous three seasons, the trial area exhibited moderate to severe P deficiency symptoms.

The areas were mapped in August, 1993 for presence and severity of foliar symptoms in anticipation of trial work. The vines were spur-pruned uniformly in November, 1993 and on 15th April, 1994 applying the short pruning technique of leaving 2-3 buds per cane. Row and vine spacing were 2mx1.5m. The vines were trellised on a single wire at 1.5m height onto which fruiting canes are wrapped. Sixteen vines were put under each treatment, such that four vines on each side acted as guard plants and eight vines formed the sampling unit.

### 3.2 Soil sampling

Soil samples were taken from three locations in Dodoma Capital City district in order to evaluate the P fertility status at the beginning of the studies. The soils at each location were sampled to a depth of 15 cm. Sampling was done in concentric circles around grapevine plants at intervals of 15 cm up to 75 cm both along and perpendicular to the trench. This was done in order to take care of the suspected fertility gradient due to farmyard manure application in the trench during field establishment and annual application of 20 kg of farmyard manure per tree thereafter. From each location eight samples were randomly collected and composited by distance from the trunk as follows:

0- 15 cm along and perpendicular to the trench.

15-30 cm along and perpendicular to the trench.

30-45 cm along the trench.

45-60 cm along the trench.

60-75 cm along the trench.

30-45 cm perpendicular to the trench.

45-60 cm perpendicular to the trench.

60-75 cm perpendicular to the trench.

The samples were air-dried and ground to pass through a 2mm sieve.

For the determination of the general fertility status of the experimental plots, four surface (0-30 cm) soil samples from each location were randomly collected from inter-row spaces to cover the experimental plots. The samples were composited, air-dried and ground to pass through a 2 mm sieve. A portion of the soil was used for the determination of the soil physical and chemical properties and the rest used for incubation studies.

### **3.3 Soil classification**

For soil classification, three soil profiles were excavated, one at each location. Soils were classified up to subgroup level using the Soil Taxonomy System (Soil Survey Staff, 1990) and up to level-2 soil-unit names according to the FAO-UNESCO Soil Classification System (FAO-UNESCO, 1989). The experimental soils were classified as Ustic Torriorthents, Acrustoxic Kanhaplustults and Ustic Torriorthents for Msalato-A, Msalato-Manispaa and Veyula-Makutupora sites respectively, using the Soil Taxonomy System (Soil Survey Staff, 1990). The description of the respective soil profiles used in the classification are given in Appendix 2.

### 3.4 Soil analysis

Soil pH was measured in 1:2.5 soil water suspension using a pH meter (Maclean, 1982). Organic carbon was analysed following the Walkley and Black method (Allison, 1965) and total N by the macro-Kjeldahl digestion followed by distillation (Bremner, 1965). Extractable P was determined by the Bray No.1 method (Bray and Kurtz, 1945), but colour development was done by the ascorbic acid-molybdate blue method as described by Murphy and Riley (1962). Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method (Rhoades, 1982). Exchangeable K and Na in the ammonium acetate leachates were determined by flame photometry while Ca and Mg were analysed by atomic absorption spectrophotometry. Exchangeable Al and H were extracted by leaching with 1M KCl as described by Thomas (1982) and determined by titration. Texture was determined by the Bouyoucos hydrometer method as outlined by Day (1965). These soil properties are summarized in Tables 1 and 4.

### 3.5 Phosphate and Nitrogen Fertilizers

The concentration of major elements in the Minjingu PR used is given in Table 2. Triple superphosphate (46%  $P_2O_5$ ) and calcium ammonium nitrate (26% N) were used as sources of water soluble P and N, respectively.

### 3.6 Incubation study

One incubation experiment was carried out with each soil to investigate the dissolution of P sources in the soils. In this study, 150 g of air-dry sieved soil samples were weighed into 500 ml containers. Samples of the ground P sources (<0.15 mm) were then thoroughly mixed with the soil samples at a concentration of 500 mg P/kg. A control was included in each case and all treatments were duplicated. The treatments were brought to field capacity using distilled water and incubated at 25 °C for up to 90 days. Subsamples (5 g) were withdrawn from the incubated soils at fortnight intervals for P extraction and analysis. Phosphorus was extracted from the samples using 0.5 M NaOH as described by Mackay et al. (1986). In this procedure, the 0.5 M NaOH removes non-occluded Al-P and Fe-P from a soil (Syers et al., 1972). But as minerals of the apatite group do not dissolve to any significant extent in this reagent (Chang and Jackson, 1957), then any increase in NaOH-extractable P in a soil to which a PR is added should provide an estimate of the amount of P dissolved from the PR (Mackay et al., 1986). The procedure involved shaking 5 g of soil with 0.5 M NaOH at a soil/solution ratio of 1:100 for 16 hrs, following a prewash with 1M NaCl for 1 hr. NaCl removed any free or exchangeable Ca<sup>2+</sup>, thus preventing the precipitation of Ca(OH)<sub>2</sub> and sorption of inorganic P (Syers et al., 1972).

Phosphorus in the extracts was determined by the ascorbic acid-molybdate blue method as described by Murphy and Riley (1962). The extent of dissolution was taken as the difference in P content between treated samples and control at a given sampling time.

### 3.7 Field experiments

One fertilizer experiment was conducted at each of the three locations. At each site TSP and Minjingu PR were compared as sources of P for grape vines.

The treatments were as follows;

- (i) control
- (ii) TSP 25 g P/vine which is equivalent to 84 kg P/ha
- (iii) TSP 50 g P/vine which is equivalent to 168 kg P/ha
- (iv) TSP 101 g P/vine which is equivalent to 336 kg P/ha
- (v) MPR 25 g P/vine which is equivalent to 84 kg P/ha
- (vi) MPR 50 g P/vine which is equivalent to 168 kg P/ha
- (vii) MPR 101 g P/vine which is equivalent to 336 kg P/ha

Treatments were applied on the 35<sup>th</sup> day after pruning. Each treatment was applied on 16 vines and the treatments were arranged in a complete randomized block design with four replications. A basal N application of 91 g per vine (equivalent to 303 kg N/ha) was applied to all the vines along with the respective P fertilizer doses. The fertilizers were applied at a radius of 10cm around the vines and 15cm deep into the soil. The plots were

irrigated adequately at Msalato A and Veyula-Makutupora sites due to delayed onset of rain (Appendix 3). As there were no irrigation facilities at Msalato-Manispaa vineyard, the plot was not irrigated. Fungicides and insecticides sprays at fortnight intervals started when the test plants had acquired five leaves following pruning. Dithane M45 and kocide at the rate of 100g/20L were used to control downy mildew (*Plasmopara viticola*) disease. Sandofan at the rate of 80g/20L was used to control powdery mildew (*Uncinula necator*) disease. To control aphids, and thrips actellic at the rate of 10 ml/20L was used.

### 3.8 Petiole samples

Twenty-five leaf petioles adjacent to the clusters were collected at the end of the bloom period from each treatment for the determination of N, P, K and Ca concentrations. Sampling at bloom stage was chosen for repeatability at this phenological stage and for comparison with established critical levels (Christensen et al., 1978). The petioles were washed in tapwater and then with distilled water. They were dried at 70 °C for 48 hours and ground to pass through a 1mm sieve. Plant samples were ashed in a muffle furnace at 450 °C for 12 hr and the ash was dissolved in 1N HCl (Juo, 1979). Phosphorus in the aliquots was determined by the ascorbic

acid-molybdate blue method as described by Murphy and Riley (1962). Tissue K and Ca were determined by flame photometry. Total N in plant material was determined by the macro-Kjeldahl digestion followed by distillation (Bremner, 1965).

### 3.9 Yield parameters

In addition to P and Ca concentrations in petiole samples taken at full bloom (66 days after applying treatments), clusters/vine (90 days after applying treatments) and grape yield were also determined.

### 3.10 Data analysis

The relative agronomic effectiveness (RAE) values were computed using yield data according to a formula described by Engelstad, Jugsujinda and De Datta (1974), viz:

$$\text{RAE} = \frac{Y_f - Y_c}{Y_r - Y_c} \times 100$$

Where:

Y<sub>f</sub> = Yield due to one of the tested fertilizer ( in this case Minjingu PR)

Y<sub>r</sub> = Yield due to reference fertilizer (in this case TSP)

Y<sub>c</sub> = Yield obtained in control treatment.

### 3.10.1 Statistical analysis

Yields, P and Ca uptake data were analysed using standard analysis of variance procedure (Steel and Torrie, 1980). The New Duncans Multiple Range Test (NDMRT) was used to compare differences between means.

**CHAPTER FOUR****RESULTS AND DISCUSSION****4.1 Properties of the experimental Soils and Minjingu PR****4.1.1 Soils**

Some physical and chemical properties of the experimental soils are shown in Table 1 but only the properties crucial to PR effectiveness will be highlighted following a guide for interpreting analytical results reported by Acres (1983). Msalato A, Msalato-Manispaa and Veyula-Makutupora soils were acidic and low in exchangeable Ca. Msalato A had low Bray 1 extractable P whereas Msalato-Manispaa soil contained even lower Bray 1 extractable P. On the other hand Veyula-Makutupora soil contained moderate Bray 1 extractable P. Even though the P critical level for grapes in Dodoma has not been determined, observed P deficiency symptoms in the experimental vineyards indicated that soils needed supplemental P.

Table 1: Some physico-chemical properties of the experimental soils

Soil	pH	H <sub>2</sub> O	OC	KCl (%)	Total N	Bray-1 P	CEC	Exchangeable cations				Particle size analysis (%)			Textural class
								Ca	Mg	Na	K	Sand	Silt	Clay	
								----- me/100 g -----							
MA	5.5	4.0	0.62	0.06	15.8	9.5	2.0	0.54	0.09	0.66	66	5	29	SCL	
MM	5.7	4.8	0.62	0.08	8.2	13.3	3.0	1.09	0.09	1.33	55	3	42	SC	
VM	5.5	4.2	0.68	0.08	26.9	15.5	3.0	0.81	0.09	1.33	57	3	40	SC	

MA - Msalato A  
MM - Msalato Manispaa  
VM - Veyuia-Makutupora  
OC - Organic carbon

#### 4.1.2 Phosphate Materials

The chemical composition of the Minjingu PR used in the study is as shown in Table 2. The rock had high concentration of  $P_2O_5$ , CaO and is a sedimentary phosphorite in nature (Harris, 1981). Sedimentary phosphates have proved beneficial for direct application as they consist of fairly open, loosely consolidated aggregates of microcrystals with relatively large specific surface area making them more reactive (Khasawneh and Doll, 1978). Minjingu PR with 5.6% ammonium citrate (pH 7) soluble  $P_2O_5$  is comparable to values for very reactive PR, such as the one from North Carolina (Leon et al., 1986), suggesting that it may behave similarly.

#### 4.2 Incubation study

One incubation experiment was conducted to study the rate of dissolution of Minjingu PR in three soils (Table 1) over 90 days as described above (section 3.6). The extent of dissolution was taken as the difference in P content between treated sample and control at each sampling time.

##### 4.2.1 Results

The amount of NaOH-extractable P in soils incubated with Minjingu PR increased steadily with time relative to the control and reached a maximum at approximately 45 days

Table 2: Chemical analysis of Minjingu phosphate rock

Major constituent	P <sub>2</sub> O <sub>5</sub>	CaO	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	F	S	SiO <sub>2</sub>	CO <sub>2</sub>	
Total CS <sup>a</sup>												
Concentration (Wt%)	29	5.6	41.7	1.2	0.4	3.20	1.30	0.78	3.1	< 0.1	9.4	3.1

<sup>a</sup> Analysed at IFDC, Muscles Shoals, Alabama by x-ray fluorescence

<sup>b</sup> CS P<sub>2</sub>O<sub>5</sub> = P<sub>2</sub>O<sub>5</sub> extracted by neutral normal ammonium citrate solution

Table 3: Changes in NaOH extractable P in soils over 90 days following addition of 500 mg P/kg (expressed as percentage of amount of P applied)

Sample	Material	Time in days							
		0	7	14	30	45	60	75	90
MA	TSP	33.7	65.6	65.6	65.6	65.6	60.6	57.4	57.0
	MPR	3.5	15.0	18.6	29.2	62.1	62.0	62.2	62.0
MM	TSP	32.3	66.8	66.8	66.8	66.8	61.8	57.8	56.0
	MPR	0.8	11.6	18.1	30.2	51.8	51.8	51.8	52.0
VM	TSP	53.0	62.2	74.3	62.2	62.2	60.2	58.0	57.0
	MPR	3.8	9.2	19.7	20.2	42.6	42.6	42.8	42.6

MA = Msalato A  
MM = Msalato - Manispaa  
VM = Veyula-Makutupora

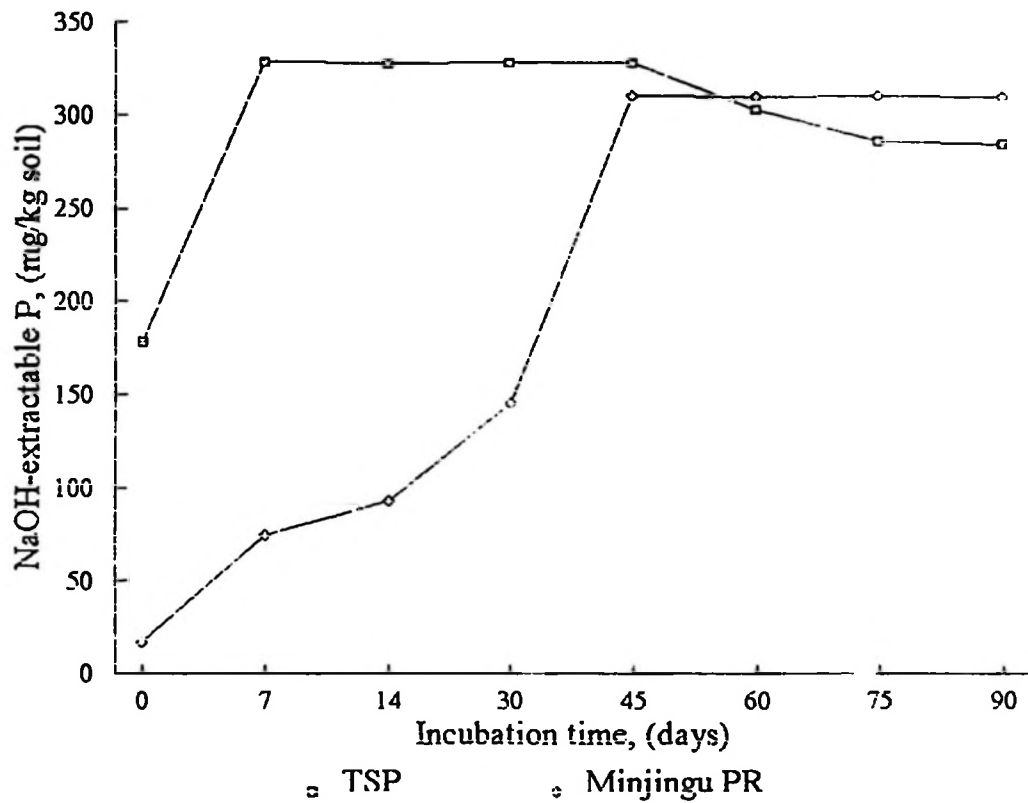


Figure 1. Changes in sodium hydroxide extractable P with time in Msalato-A soil treated with TSP or Minjingu PR at 500mg P/kg soil.

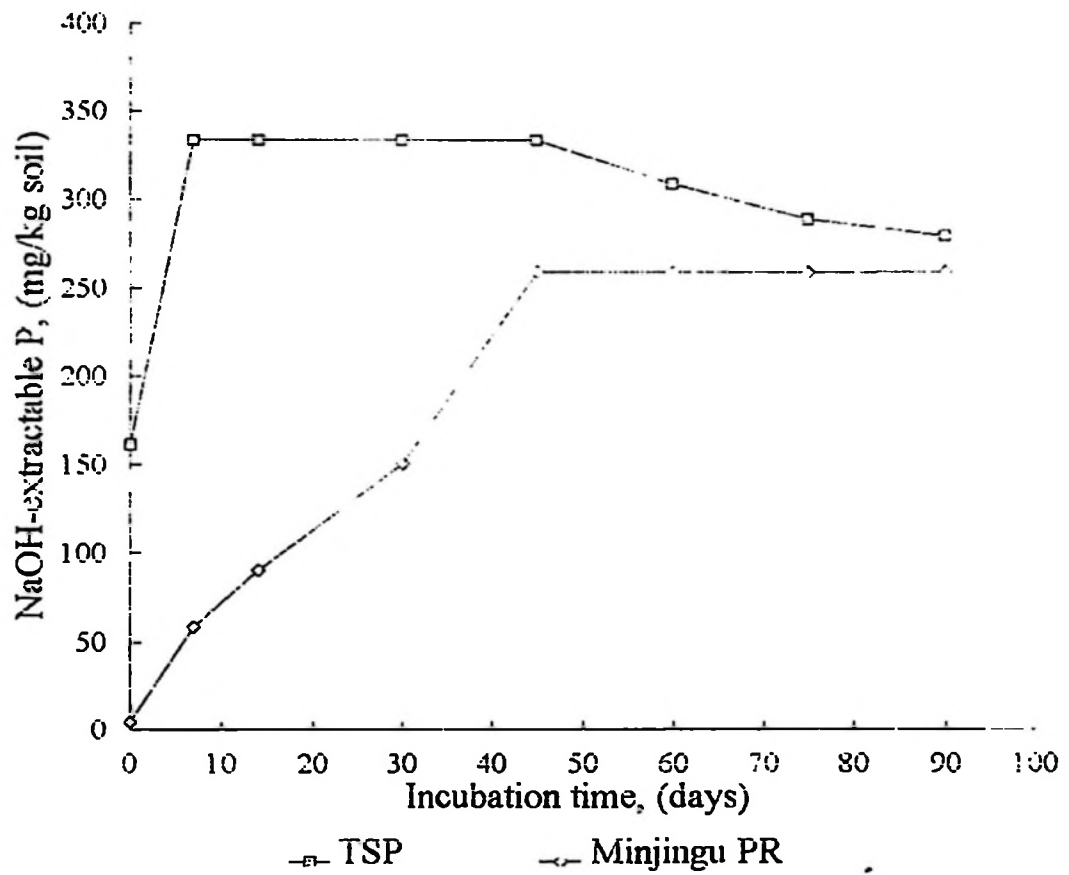


Figure 2. Changes in sodium hydroxide extractable P with time in Msalato - Manispaa soil treated with TSP or Minjingu PR at 500 mg P/ kg soil.

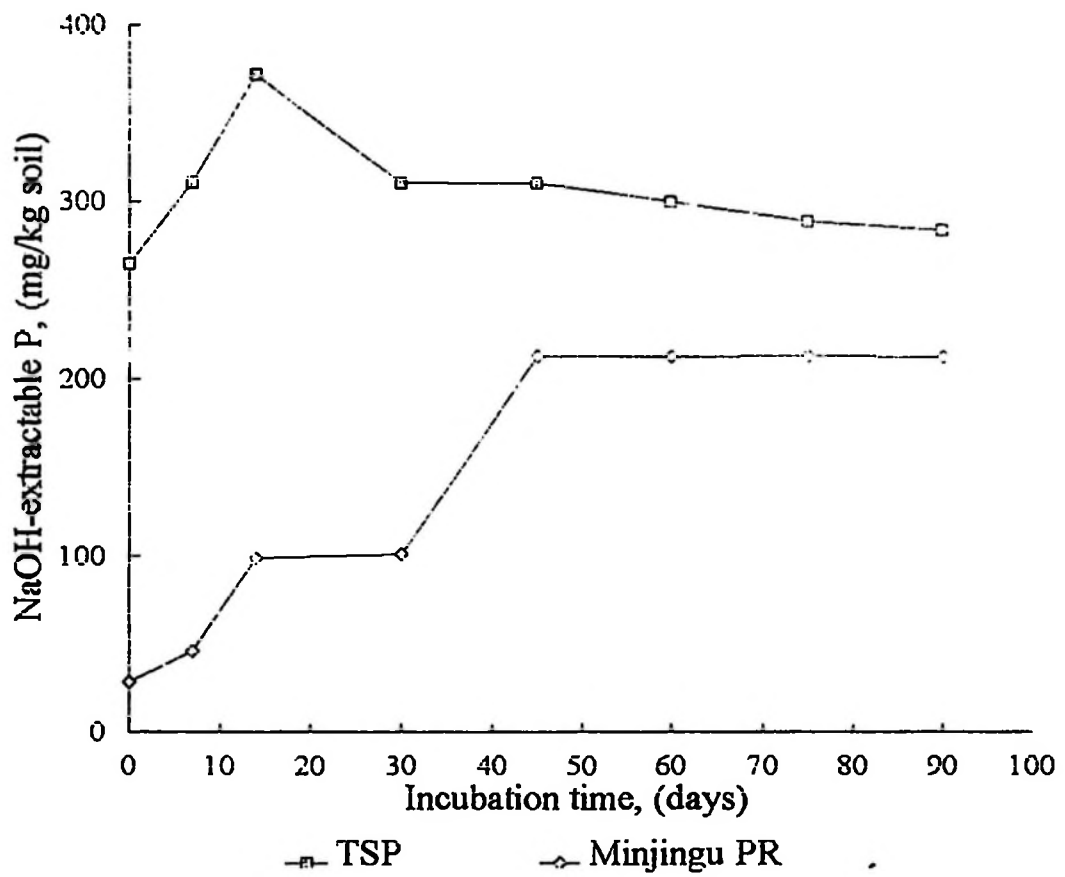


Figure 3. Changes in sodium hydroxide extractable P with time in Veyula-Makutopora soil treated with TSP or Minjingu PR at 500mg P/kg soil.

(Figs 1, 2 and 3). Mackay et al. (1986) reported similar trend. The maximum for Msalato A was 310 mg P/kg , which was equivalent to 62% of P applied as Minjingu PR (Table 3). For Msalato-Manispaa soil, the maximum was 259 mg P/kg which was equivalent to 52% of P applied as Minjingu PR. Whereas for Veyula-Makutupora soil, the maximum was 213 mg P/kg which was equivalent to 42% of P applied as Minjingu PR. On the other hand, the amount of NaOH-extractable P in incubated soils to which TSP had been added decreased slightly after 45 days (Figs 1,2 and 3) and did not increase steadily with incubation time as compared to the amount extracted from the Minjingu PR. The difference in the amount of NaOH extractable P may be attributed to the fact that initial dissolution of water soluble P sources such as TSP is not influenced by factors which influence dissolution of PR in soils (Syers and Mackay, 1986).

Data in Figs 1,2 and 3 show that Minjingu PR dissolved to differing extents in the three soils, but in each case reached equilibrium after about 45 days. Differences in the amounts of Minjingu PR that had dissolved in the three soils was attributed to differences in soil properties (Table 1). The extent of dissolution was 310 mg P/kg for Msalato A, 259 mg P/kg for Msalato-Manispaa and 213 mgP/kg for Veyula-Makutupora at equilibrium. The dissolution of the Minjingu PR in these soils followed a pattern similar to the level of Bray 1

extractable P and exchangeable Ca of the soils (Table 1). Msalato A soils with 15.8 mg P/kg soil and 21% Ca saturation at equilibrium had released about 62% of P applied as Minjingu PR (Table 3). Msalato-Manispaa soils with 8.2 mgP/kg soil and 22.6% Ca saturation released about 52% of P applied as Minjingu PR at equilibrium, whereas Veyula-Makutupora soils with 26.9 mg P/kg soil and 19.4% Ca saturation released 42.8% of P applied as Minjingu PR (Table 3). Bray 1 extractable P is the only soil property which showed large difference among the three soils and might have accounted more for the differences in NaOH-extractable P for Msalato-A and Veyula-Makutupora soils. These results are in agreement with those of Robinson and Syers (1990) who demonstrated that Ca and P sinks are crucial factors in P solubilization. Similarly, Khasawneh and Doll (1978) demonstrated that a sink for  $H_2PO_4$  favours PR dissolution. Differences in NaOH-extractable P among the three soils implies that Minjingu PR has different ability to supply P to plants in these soils.

Changes in NaOH-extractable P in TSP treated samples (Fig. 1,2 and 3) levelled off from 7th day of incubation and remained more-or-less constant up to the 45th day after which slight decreases occurred from the 60th up to the 90th day of incubation. The tendency for NaOH-extractable P to increase with time in Minjingu PR treated

samples in contrast to TSP, implies that Minjingu PR is dissolved more slowly than TSP suggesting that it is more suitable for permanent crops and forests whose P requirements are distributed over longer periods of time.

#### 4.3 Field experiment

This study was initiated to determine the effect of P application on grape yield and to evaluate the agronomic effectiveness of Minjingu PR on grape production in Dodoma Capital City district. The plant parameters used to evaluate the treatment effects were number of clusters/vine, grape yield, P and Ca uptake.

##### 4.3.1 Initial fertility status of the trial sites

Table 4 shows some of the chemical properties of soils sampled in concentric circles around the trunk at the beginning of the study. The data revealed the existence of fertility gradients with fertility status decreasing with increasing distance from the trunk. Soil samples along the trench and between 30-45cm from the trunk perpendicular to the trench were slightly acidic to neutral. Soil samples taken from 45-75cm away from the trunk and perpendicular to the trench were acidic. At Msalato A, available P declined from 61 mg P/kg to 41 mg P/kg for samples taken along the trench between 0-45 cm

Table 4: pH, Total N, available P and exchangeable Ca status at the beginning of the study

Location	Sampling distance (cm)	pH (H <sub>2</sub> O)	Total N (%)	P mg kg <sup>-1</sup>	Exchangeable Ca me/100g
Msalato A	0-15AP	7.1	0.13	61.40	5.50
	15-30AP	7.2	0.20	53.51	10.00
	30-45A	7.2	0.14	41.23	5.50
	45-60A	6.9	0.02	26.32	3.75
	60-75A	7.0	0.04	21.05	2.00
	30-45P	7.1	0.01	26.32	5.00
	45-60P	5.5	0.01	1.75	1.00
	60-75P	4.6	0.01	Trace	2.00
Msalato-Manispaa	0-15AP	6.3	0.10	46.05	1.00
	15-30AP	6.6	0.10	45.41	2.50
	30-45A	6.5	0.08	19.49	1.97
	45-60A	6.8	0.07	17.46	3.74
	60-75A	6.6	0.04	16.67	2.00
	30-45P	6.4	0.04	8.77	2.00
	45-60P	5.8	0.03	5.85	1.00
	60-75P	6.0	0.02	5.26	2.00
Veyula-Makutupora	0-15AP	7.7	0.06	54.58	3.74
	15-30AP	7.5	0.04	46.49	3.74
	30-45A	6.9	0.04	41.23	2.74
	45-60A	7.3	0.03	40.56	2.00
	60-75A	6.7	0.01	36.84	2.74
	30-45P	5.8	0.01	19.30	1.00
	45-60P	4.9	0.02	5.26	1.00
	60-75P	4.8	0.02	5.26	2.00

NB: AP = Composite samples taken along the trench and perpendicular to the trench  
A = Samples taken along the trench only  
P = Samples taken perpendicular to the trench

from the trunk. From 45 up to 75 cm from the trunk and along the trench, available P declined from 26 to 21 mg P/kg. Available P for samples taken between 45-75 cm from the trunk and perpendicular to the trench declined from 1.75 mg P/kg to trace. A similar trend was manifested by nitrogen and exchangeable Ca. At Msalato-Manispaa, available P for samples taken along the trench between 0-45 cm from the trunk declined from 46-19 mg P/kg, whereas for samples taken between 45-75 cm from the trunk along the trench, available P declined from 19-16 mg P/kg. For samples taken between 45-75 cm from the trunk and perpendicular to the trench, available P declined from 8 to 5 mg P/kg. At Veyula-Makutupora site, available P declined from 54-41 mg P/kg for samples taken between 0-45 cm from the trunk along the trench. Available P declined from 41-36 mg P/kg for samples taken between 45-75 cm from the trunk along the trench and declined from 19-5 mg P/kg for samples taken between 45-75 cm from the trunk perpendicular to the trench. A similar trend was manifested by nitrogen and exchangeable Ca at Msalato-Manispaa and Veyula-Makutupora sites.

Data in Table 1 do not compare well with data in Table 4 for samples taken along the trench in terms of soil pH and available P. Along the trench pH and available P ranged from 7.1-6.8 and from 61-26 mg P/kg, respectively. Whereas in Table 1, pH and available P

ranged from 5.5-5.7 and from 26-8 mg P/kg, respectively. However, pH, exchangeable Ca and available P values in Table 1 compare well with those in Table 4 for samples taken between 45-75 cm from the trunk and perpendicular to the trench. It is evident from Table 4 that pH, N, Ca and P values along the trench were higher than those outside the trench. This is attributed to the initial and annual applications of manure (section 3.2) and rooting habit of the vines. The application of manure close to the trunk concentrates nutrients in this zone. In addition the decrease in available nutrient levels at the 60-75 cm along the trench was partly caused by greater uptake of nutrients in this zone. Existence of greater root activity in this zone has been reported by Brar *et al.* (1986). They reported that about 77-84% of active roots were found in the top 50 cm at a distance of 80cm from the main stem. Dasaradhi and Afzalunnissa (1977) reported that the root activity was confined to the first 25 cm depth and laterally at 60-90 cm from the trunk all round. Iyegar and Murthy (1989) using *Citrus reticulata* as a test crop also reported similar results.

#### 4.3.2 Results of Field trials

Data for number of clusters per vine, grape yield and leaf petiole P and Ca contents at full bloom for the

November, 1993 pruning season are given in Table 5.

Differences in the number of clusters per vine as a result of treatments were significant at all locations. The number of clusters per vine increased over the control with rates of P application for both P sources at Veyula-Makutupora site, but TSP was superior to Minjingu PR at levels 2 and 3. At Msalato A Minjingu PR increased significantly the number of clusters/vine over the control at levels 2 and 3 whereas TSP decreased significantly the number of clusters /vine below the control at levels 1 and 3 but the second P level increased the number of clusters/vine significantly. The opposite trend was experienced at Msalato-Manispaa where P application decreased significantly the number of clusters/vine over the control with exception of TSP at level 3 where the number of clusters/vine increased significantly over the control.

Grape yield data more or less followed similar trends as those observed for number of clusters/vine. Fruit yield increased over the control with rates of applied P fertilizers. The P sources differed significantly with TSP being superior to Minjingu PR at Msalato A and Msalato-Manispaa. Similarly, at Veyula-Makutupora, fruit yield increased over the control with rates of applied P fertilizers. But P source was a significant factor at level 2 only, with TSP being superior to Minjingu PR.

**Table 5: Effects of phosphorus application on number of clusters/vine, grape yield and petiole N, P, K and Ca at full bloom for the November, 1993 pruning season**

Location	Treat		Cluster/ vine	Yield ton/ha	% nutrient conc.			
	P source	Rate (kg/ha)			N	P	Ca	K
MA	Control	0	5.76c	3.93e	0.83	0.55	0.50	2.32
	P1TSP	84	5.20d	5.10b	0.93	0.69	0.53	1.99
	P2TSP	168	7.25ab	5.31ab	0.96	0.72	0.50	2.01
	P3TSP	336	3.25e	5.62a	1.00	0.61	0.35	2.03
	P1MPR	84	6.00c	4.47d	0.82	0.58	0.54	2.83
	P2MPR	168	7.75a	4.58cd	0.90	0.67	0.54	2.30
	P3MPR	336	7.00b	4.97bc	0.93	0.56	0.50	1.83
	CV%		15.59	17.11	1.28	6.10	2.62	2.81
	LSD		0.53	0.47	ns	ns	ns	ns
MM	Control	0	5.00b	3.64f	0.67	0.41	0.69	0.93
	P1TSP	84	4.50c	4.11de	1.00	0.55	0.63	1.84
	P2TSP	168	3.25d	5.00c	1.03	0.44	0.71	1.58
	P3TSP	336	5.75a	6.09a	1.03	0.46	0.71	1.92
	P1MPR	84	2.50e	3.88e	0.90	0.50	0.62	1.92
	P2MPR	168	4.75bc	4.22d	0.91	0.43	0.71	1.91
	P3MPR	336	4.7bc	5.50b	1.04	0.37	0.81	1.92
	CV %		18.06	10.61	1.03	3.12	2.19	0.91
	LSD		0.44	0.27	ns	ns	ns	ns
VM	Control	0	5.00e	2.86d	0.84	0.50	0.50	2.90
	P1TSP	84	8.00b	4.08bc	0.97	0.63	0.54	3.06
	P2TSP	168	9.00a	4.67a	0.98	0.58	0.50	2.41
	P3TSP	336	7.25c	3.83c	1.01	0.71	0.50	2.59
	P1MPR	84	7.75bc	3.93bc	0.84	0.61	0.62	2.55
	P2MPR	168	6.25d	4.25b	0.90	0.68	0.63	2.04
	P3MPR	336	6.25d	3.77c	1.01	0.68	0.56	2.83
	CV %		14.58	15.71	2.99	1.78	3.40	2.64
	LSD		0.58	0.35	ns	ns	ns	ns

Means within a column followed by a common letter or no letter are not significantly different at the 5% level according to the Duncan's New Multiple Range Test

ns = non significant  
MA = Msalato - A  
MM = Msalato - Manispa  
VM = Veyula - Makutupora

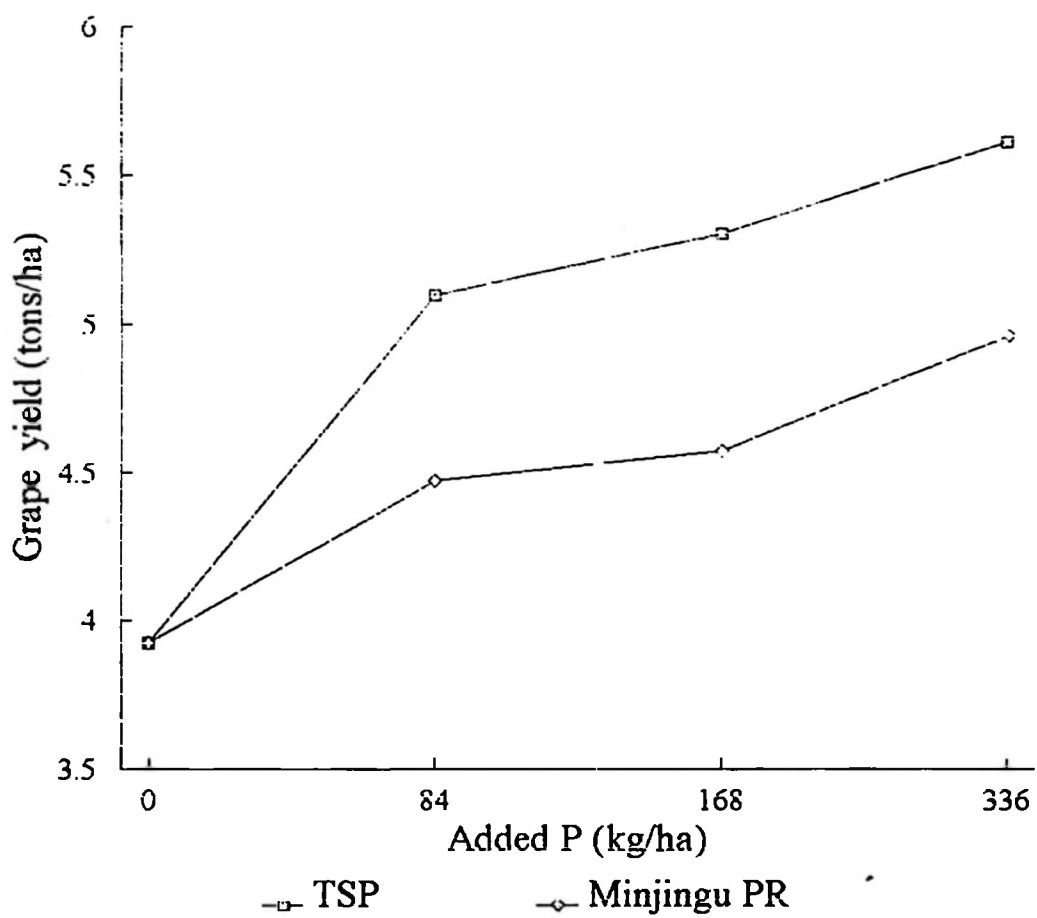


Figure 4. Effects of two sources of P on yield of rain season grape grown with supplemental irrigation at Msalato - A

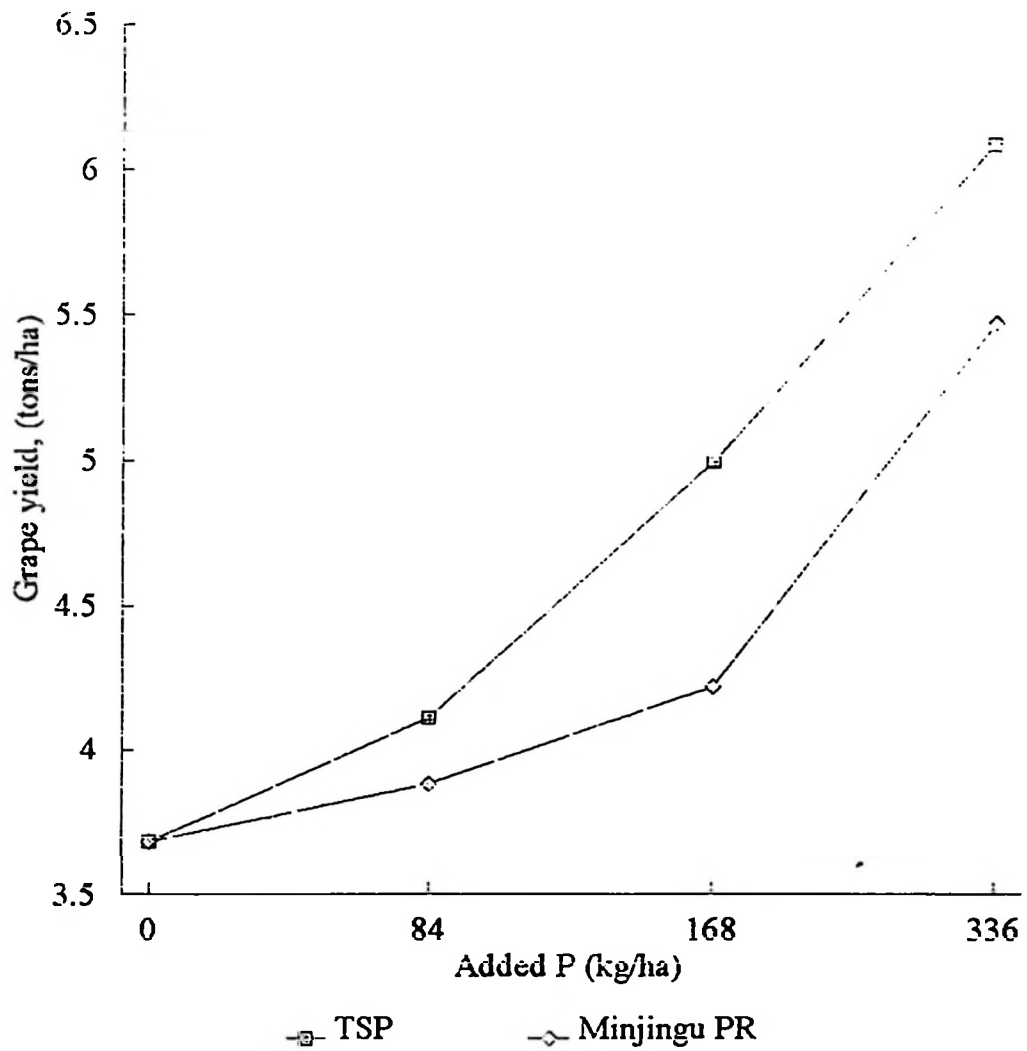


Figure 5. Effects of two sources of P on yield of rain season grape grown without supplemental irrigation at Msalato - Manispaa

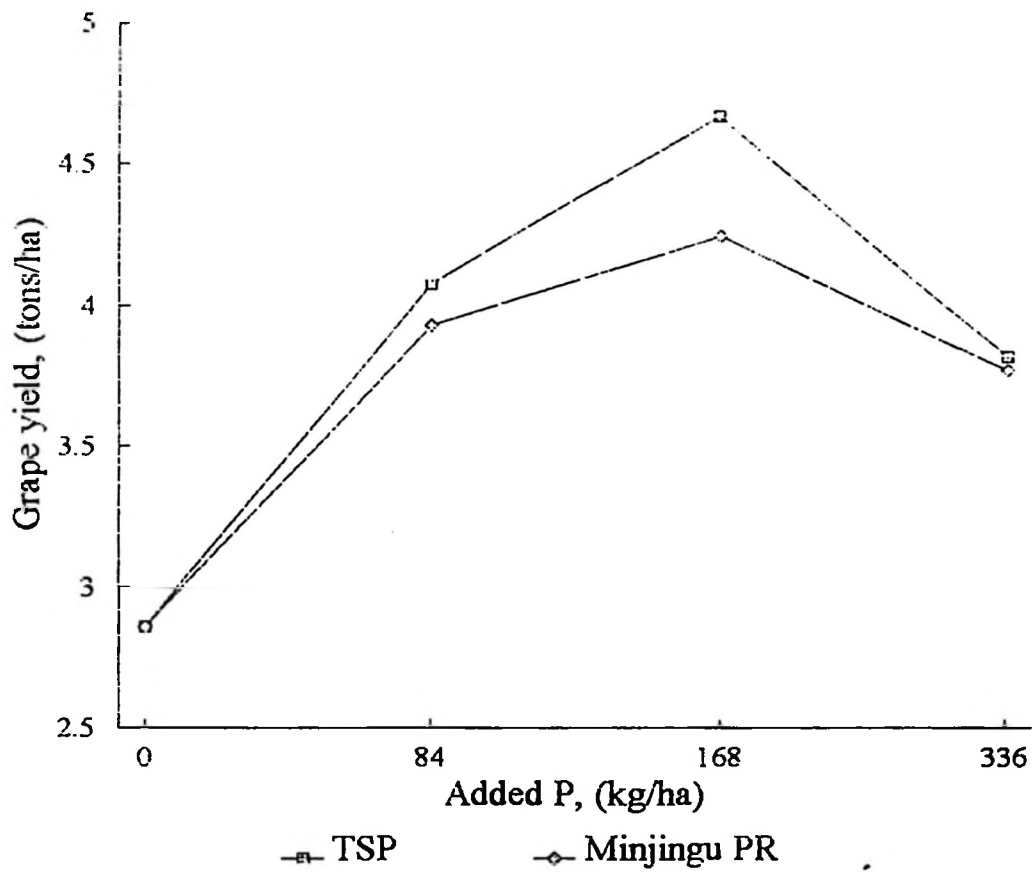


Figure 6. Effects of two sources of P on yield of rain season grape grown with supplemental irrigation at Veyula-Makutopora.

Application of P at 336 kg P/ha from both TSP and Minjingu PR resulted in yield depression at Veyula-Makutupora (Fig. 6). These results suggested that the highest P rate caused some nutrient imbalance which depressed grape yields. It is known that excessive amounts of P may induce Zn deficiencies, thus leading to lower yields (Christensen et al., 1978). However, no Zn deficiency symptoms were detected in the experimental plots.

Of the three sites, Msalato-Manispaa soils gave better yield response to P-fertilization. The pattern of response observed followed the order Msalato-Manispaa > Msalato A > Veyula-Makutupora (Table 5 and Figs 4, 5 and 6). Inspection of the data in Table 5 shows that the optimum rate of TSP is 168 kg P/ha at Msalato A and Veyula-Makutupora whereas at Msalato-Manispaa no optimum rate could be estimated because yield was still increasing even at the highest rate of added P (336 kg P/ha) probably because the latter site had lower P level initially. A similar trend was found with Minjingu PR. These rates are thus tentatively recommended on these sites but the build up in P with time should be monitored.

Also observed even though not recorded was the increased number of berries/cluster and cluster weight over the control with increased rates of P application. This behaviour accounts better for the observed lower yields in vines which received no P. This observation is

consistent with that of Skinner and Matthew (1989) who demonstrated that adequate P was necessary for the initiation and maintenance of clusters. These workers also found that whereas initiation of clusters occurred when P was deficient, maintenance of clusters was nil under such conditions. Matthews and Anderson (1989) also reported similar results that most of the variations in yield they observed in their study was explained by variations in the number of berries per cluster.

During the November 1993 pruning season, phosphorus application increased P concentration in petiole samples from all sites except for the highest rate of Minjingu PR at Msalato-Manispaa which tended to decrease concentration (Table 5). In addition all the P concentration values were within or above the adequate range of 0.3-0.6% reported by Cook and Wheeler (1976). Since P was not severely limiting even in the control the observed grape yield response is probably due to increase in fruit size and less shedding of fruits at high P rates.

The data in Table 5 also indicated petiole N and K levels at bloom stage to be higher than standards given by Larsen (1955) and Christensen et al. (1978), respectively indicating that N and K were not limiting in this study. Larsen (1955) established 0.8% N to be the standard value in petioles at bloom stage. In the case of K Christensen et al. (1978) found 1.5% K to be the standard value in

petioles at bloom stage. Petiole Ca concentration was increased by P application but not significantly. The values ranged from 0.35% to 0.81% for the November, 1993 pruning season. Minjingu PR treatments gave slightly higher petiole Ca concentration values than TSP suggesting Minjingu PR may be a better source of Ca than TSP.

Results of the April 1994 pruning season are given in Table 6. At Msalato A and Veyula-Makutupora P application did not affect number of clusters/vine significantly. At Msalato-Manispaa, Minjingu PR depressed number of clusters/vine while with TSP, the first two levels depressed number of clusters/vine significantly while the highest rate did not affect cluster numbers/vine significantly.

P concentration in the petiole was low at Msalato-Manispaa bordering on deficiency levels in the control. On the other two sites the concentration was in the adequate range but lower than that for samples taken on 11th Feb. 1994 (Table 6). This indicated that P supply decreased with time and thus may limit yield of the second crop. Unfortunately time did not permit waiting for the second grape harvest and thus the final situation is not known.

The yield as measured by number of clusters per vine was much higher in the April, 1994 pruning season than in the November, 1993 pruning season at Msalato A and Msalato-Manispaa sites (Tables 5 and 6). This was expected since

Table 6: Effects of phosphorus application on number of clusters/vine and petiole P, K and Ca at full bloom for the April, 1994 pruning season

Location	Treat.		Clusters/ vine	% nutrient concn.		
	P source	kg/ha		P	K	Ca
MA	Control	0	8.54	0.42	2.10	0.29
	P1TSP	84	9.87	0.42	2.10	0.28
	P2TSP	168	8.32	0.49	2.69	0.28
	P3TSP	336	7.16	0.46	2.05	0.26
	P1MPR	84	7.94	0.46	1.79	0.30
	P2MPR	168	8.57	0.48	2.36	0.40
	P3MPR	336	8.94	0.40	1.69	0.30
	CV %		30.18	24.71	43.71	22.69
	LSD		ns	ns	ns	ns
MM	Control	0	9.28a	0.17	1.66	0.38
	P1TSP	84	6.60c	0.26	1.64	0.33
	P2TSP	168	4.69d	0.24	1.60	0.46
	P3TSP	336	9.25a	0.27	1.58	0.47
	P1MPR	84	4.82d	0.21	1.33	0.45
	P2MPR	168	7.63b	0.25	1.26	0.40
	P3MPR	336	7.97b	0.30	1.15	0.52
	CV %		47.23	29.79	18.76	21.69
	LSD		5.06	ns	ns	ns
VM	Control	0	3.56	0.29	2.32	0.28
	P1TSP	84	4.38	0.33	2.25	0.29
	P2TSP	168	4.50	0.36	2.09	0.30
	P3TSP	336	3.85	0.40	2.32	0.29
	P1MPR	84	4.69	0.33	1.91	0.32
	P2MPR	168	5.28	0.38	2.31	0.31
	P3MPR	336	4.2	0.36	1.91	0.31
	CV %		21.78	17.85	19.19	17.68
	LSD		ns	ns	ns	ns

Means within a column followed by a common letter or no letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test

ns - non significant  
MM - Msalato-Manispaa

MA - Msalato A  
VM - Veyula-Makutupora

P nutrition to the vines was improved by P application as evidenced by P concentration at bloom stage for petioles sampled on 11th Feb. 1994 (Table 5). It is known that fruiting potential or the yield capacity of a grapevine is indicated by the fruitfulness of the buds, which have been initiated during the previous season (Randhawa, 1967). The promotive effect of P on initiation and differentiation of inflorescence primordia in grape has also been reported by Fleming, (1961) and Kobayashi (1960). However, at Veyula-Makutupora site, the April, 1994 pruning season recorded lower cluster numbers per vine than the November, 1993 pruning season. These results are related to the levels of extractable P found in soils at the beginning of the study (Tables 1 and 4) in that response was observed in soils testing low in P (<15 mg P/kg) while little response was observed in the relatively rich Veyula-Makutupora soils.

The grape yields obtained were below the average yield of 15-30 tonnes/ha obtained in warm temperate climates (Wagner, 1907) (as quoted by Perold, 1927). This is in line with Winkler (1974) who stated that in tropical climates the vine produced small crops of very poor quality. High temperatures reduces fruit growth (Kliever and Lider, 1970). However, significant increases in yield over the control with increased rates of P application confirmed the need for supplemental P in these soils. It

Table 7: Relative effectiveness of Minjingu phosphate rock (MPR) vs triple superphosphate (TSP) for November, 1993 pruning season

Treatment	Rate kgP/ha	Experimental soil		
		Msalato-A	Msalato- Manispaa	Veyula- Makutupora
Relative agronomic effectiveness				
TSP1	84	100	100	100
MPR1	84	46	51	88
TSP2	168	100	100	100
MPR2	168	47	65	77
TSP3	336	100	100	100
MPR3	336	62	76	95
Relative efficiency in P uptake				
TSP1	84	100	100	100
MPR1	84	21	64	85
TSP2	168	100	100	100
MPR2	168	71	67	225
TSP3	336	100	100	100
MPR3	336	17	80	86

is evident from the data given in Table 7 that Minjingu PR gave yield increases from 46% to 95% of that obtained with ordinary TSP. This could be attributed to the correspondingly low P uptake values associated with the Minjingu PR treatments (Tables 5 and 6) due to its relatively slow dissolution rates as revealed in the incubation study (Figs 1, 2 and 3). The trend of results observed compares with that of Miranda *et al.* (1970) (as quoted by Fenster and Leon, 1978). The authors tested three PRs using corn and found them to give yield increases from 37% to 70% of that obtained with ordinary superphosphate. Similar trend of results has been reported by Marwaha *et al.* (1981) and Ikerra *et al.* (1994) both using maize as a test crop. Long term fertility trials by (Anderson, 1965; Anderson, 1970;) have shown that in most cases Minjingu PR gave positive responses which when assessed for periods of 3 to 6 years (i.e. including residual effects) were found to be equal or more than those from superphosphates. This suggests that residual effects in the current study should also be assessed.

#### 4.3.3 Residual P after harvest

Extractable P data after harvest are presented in Table 8. For Msalato A soils, TSP treatments at levels 2, 3 and MPR treatments at level 3 differed significantly from the control. TSP1, MPR1 and MPR2 did not differ

**Table 8: Effect of triple superphosphate (TSP) and Minjingu phosphate rock (MPR) on extractable P (mgP/kg) after harvest**

Treatment	Rate	Location		
	kg P/ha	Msalato-A	Msalato-Manispaa	Veyula-Makutupora
PO	0	46.1d	40.4e	49.9d
TSP1	84	69.7cd	150.9cd	114.9bcd
TSP2	168	97.8b	250.5b	170.2bc
TSP3	336	130.3a	356.1a	300.9a
MPR1	84	58.3d	65.4e	104.cd
MPR2	168	71.5bcd	97.4de	135.1bc
MPR3	336	87.3bc	175.0c	187.7b
CV %		21.7	30.5	31.2

Means within the same column followed by the same letter are not significantly different at 0.05 according to Duncan's New Multiple Range Test

significantly from the control, but treated soils had slightly higher extractable P values which increased with rates of phosphorus application. Phosphorus source was a significant factor at level 3 only even though higher extractable P values were associated with TSP treatments at all levels. This pattern of extractable P reflects the trend of yield (Table 5) which increased with increases in P levels.

For Msalato-Manispaa soils TSP treatments at levels 1, 2, 3 and MPR treatments at level 3 differed significantly from the control with P sources differing significantly. However, TSP was superior to MPR. MPR treatments at levels 1 and 2 did not differ significantly from the control, but MPR treated soils released slightly higher extractable P values than the control with the amount released increasing with increased rates of P application. The highest yield of about 6.09 t/ha was associated with the highest extractable P value of 356.14 mg P/kg soil (TSP3), suggesting that yield increases observed were due to P application.

For Veyula-Makutupora soils MPR1 and TSP1 did not differ significantly from the control. TSP1, TSP3, MPR2 and MPR3 differed significantly from the control, but TSP2, MPR2 and MPR3 were not significantly different, whereas TSP3 differed significantly from MPR at all levels. The yield decline observed at this site was

associated with higher values of extractable P from both P sources. Low extractable P values associated with MPR treated soils as compared to TSP treated soils at all levels was attributed to PR's low solubility and that is why phosphate rocks have been shown to persist in some soils for at least 40 years (Khasawneh and Doll, 1978).

Tables 7 and 9 show the relative effectiveness of the two P sources (TSP vs Minjingu PR) in respect to grape yield and P uptake, computed as per section 3.10. For all soils, the relative agronomic effectiveness (RAE) value for Minjingu PR was lower than that of TSP, suggesting that TSP had a higher fertilizer value. The RAE values increased with increasing rates of P application for Msalato A and Msalato-Manispaa soils, whereas for Veyula-Makutupora soils the RAE decreased at level 2 and then increased at level 3 (Figs. 4, 5 and 6). As regards P uptake, Minjingu PR was less effective than TSP in all soils except at level 2 for Veyula-Makutupora during the November, 1993 pruning season and again at level 2 for Msalato-Manispaa and Veyula-Makutupora for the April, 1994 pruning season. For Ca uptake, Minjingu PR was superior to TSP in all soils suggesting improved Ca supply through the dissolution of Minjingu PR in the treated soils.

**Table 9: Relative effectiveness of Minjingu phosphate rock (MPR) vs triple superphosphate (TSP) for April, pruning**

Treatment	Rate kgP/ha	Msalato-A	Msalato-Manispaa	Veyula-Makutupora
Relative efficiency in P uptake				
TSP1	84	100	100	100
MPR1	84	-	44	100
TSP2	168	100	100	100
MPR2	168	86	114	129
TSP	336	100	100	100
MPR3	336	50	60	64

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

The analysis of soils sampled concentrically around the trunk at five distances of 15cm increments at the beginning of the study revealed the existence of fertility gradients with fertility status decreasing with increasing distance from the trunk. This was attributed to application of manure close to the trunk and due to greater root activity at distances of 50-80cm from the trunk.

The results of the incubation experiment indicated that Minjingu PR dissolved to differing extents in different soils, but in each case reached equilibrium after about 45 days, indicating that Minjingu PR has different potential to supply P to plants in these soils. TSP treated samples also released different amounts of P in these soils, suggesting that these soils had different P-fixing capacities.

The results of the field experiment revealed that P application increased grape yield significantly over the control with P sources being a significant factor at all levels except level 1 for Msalato-Manispaa and levels 1 and 3 for Veyula-Makutupora sites. However, at Veyula-Makutupora site, application of P at 336 Kg/ha decreased grape yield, suggesting that this P rates might have caused some nutrient imbalances. It is evident from this

study that, the relative agronomic effectiveness value for Minjingu PR was lower than that of TSP, suggesting that TSP had a higher fertilizer value. As regards P uptake, generally Minjingu PR was less effective due to its slow dissolution rate. But Minjingu PR was more effective in Ca uptake than TSP, suggesting that as a result of PR dissolution Ca was released and made available to the test plants.

From the findings, it was concluded that:

- (1) in addition to N, P application was needed in order to optimize grape yield in Dodoma district and a tentative rate of 168 kg P/ha is recommended.
- (2) Minjingu PR was found to be a promising substitute for TSP but assessment of residual effects should be made before a definite recommendation can be made.
- (3) further research should be conducted to increase P use efficiency.

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## 7 APPENDICES

**Appendix 1: Grape sales figures for Dodoma region for  
the period 1986 - 1992**

Year	Amount received in kgs		
	Dowico <sup>1</sup>	GMS <sup>2</sup>	Total
1986	1,741,750	32,630	1,774,380
1987	1,364,010	42,708	1,406,718
1988	1,420,000	120,000	1,540,000
1989	437,000	51,144	488,144
1990	420,000	40,000	460,000
1991	410,000	41,000	448,000
1992	405,000	41,000	446,000

<sup>1</sup>Dodoma Wine Company

<sup>2</sup>General Manufacturers Supplies

Source: Dodoma Wine Company and General Manufacturers  
Supplies

**Appendix 2. Soil profile description**

**Pedon 1: Msalato A=thereafter referred to as DU1**

Date of description and sampling: 30 / 5/ 94

Authors: B.M.Msanya and G.M.R Budotela

Survey area / District: Msalato A / Dododma Capital City

location : Mr. Bukuku's vineyard at Msalato A 6° 4' 22.85" S and 35° 44'55.8" E , 14 km from Dodoma town towards Arusha, 500m from the Dodoma - Arusha main road.

Classification: (Soil Survey Staff, 1990). Ustic

Torriorthents

(FAO-UNESCO, 1989). Dystric Regosols

Elevation: About 1113.6 masl

Geological formation: Neogene system comprising undifferentiated soils

Parent material: Alluvium/Colluvium derived from granitic rocks.

Landform: (i) Physiographic position: plain.

(ii) Surrounding landform: flat or almost flat and presence of termite mound 8 m from the profile

(iii) Slope on which the profile is sited: 2% linear slope about 2000m length, South- West in direction positioned at lower quarter.

Rainfall: the annual rainfall varies from 500-700ml with an average of 500ml. The rainy season starts in December and ends in March although it may start in November and end in April thus giving a pronounced dry season of approximately 6-8 months.

Drainage: Well to excessively drained.

Moisture condition in the profile: Moist below 115 cm.

Soil moisture regime: Ustic \ Aridic

Soil temperature regime: Hyperthermic

Depth of ground water table: Too deep to affect the profile.

Presence of stones and rock outcrops: None.

Evidence of erosion: Slight sheet erosion but no sign of deposition at the site and adjacent fields.

Presence of salt or alkali: None.

Human influence: Cultivation and grazing.

Vegetation: Acacia bushes with bare spots.

#### **Description of individual horizons.**

Ap 0-10 cm Yellowish brown (10YR5/4) moist and light yellowish brown (10YR6/4) dry; sandy clay loam; soft when dry; weak single grained; fine crumb; slightly sticky and slightly plastic when wet; many fine, few coarse and common medium pores; many fine and very fine roots; clear and smooth boundary towards AC1h.

AC1h 10-30/40 cm Yellowish brown (10YR5/4) moist and brownish yellow (10YR6/6) dry; sandy clay; slightly hard when dry; massive; slightly sticky and slightly plastic when wet; many fine, few coarse and common medium pores; common very fine and few medium roots; abrupt and wavy boundary towards AC2.

AC 30/40-80 cm Yellowish brown (10YR5/6) moist and brownish yellow (10YR6/6) dry; clay; massive; slightly sticky and slightly plastic when wet; many very fine and fine, few medium pores; few medium and few very fine roots; gradual and smooth boundary towards AC3.

AC3 80-115 cm Brownish yellow (10YR6/6) moist and Yellow (10YR7/6) dry; clay; slightly hard when dry; massive; non sticky and slightly plastic when wet; many very fine and fine, few medium pores; few very fine, few medium roots; clear and smooth boundary towards AC4.

AC4 115-180 cm Yellowish brown (10YR5/6) moist; clay; very friable when moist; massive; non sticky and slightly plastic when wet; many very fine and fine, few coarse pores; few fine and few medium roots.

**Pedon 2: Msalato- Manispaa= thereafter referred to as DU2**

Date of description and sampling: 30 / 5/ 94

Authors: B.M.Msanya and G.M.R Budotela

Survey area / District: Msalato Manispaa/ Dodoma Capital  
City

Location: Manispaa's vineyard situated at 6° 0.2' 58.1" S  
and 35° 45' 27.4" E, 18km from Dodoma along Arusha,  
300m east of the Dodoma-Arusha main road.

Classification: (Soil Survey Staff, 1990). Acrustoxic  
Kanhaplustults

(FAO-UNESCO, 1989). Haplic Acrisols

Elevation: About 1140.2 masl

Geological formation: Neogene system comprising  
undifferentiated soils

Parent material: Alluvium/Colluvium derived from granitic  
rocks.

Landform: (i) Physiographic position: Upland plain

(ii) Surrounding landform: flat or almost flat

(iii) Slope on which the profile is situated:  
1-2% linear slope about 8km in length,  
positioned at upper quarter.

Rainfall: The annual rainfall varies from 500-700ml with  
an average of 500ml and a pronounced dry season  
ranging from 6-8 months.

Drainage: Well to excessively drained.

Moisture conditions in the profile: Moist bellow 88cm.

Soil moisture regime: Ustic \ Aridic

Soil temperature regime: Hyperthermic

Depth of ground water table: Too deep to affect the  
profile.

Presence of stoniness and rock outcrops: None.

Evidence of erosion: Slightly splash erosion, but no sign  
of deposition at the site and adjacent fields.

Presence of salt or alkali: none.

Human influence: Clearing and cultivation.

Vegetation: Acacia bushes with bare spots.

#### **Description of individual horizons.**

Ap 0-5 cm Dark brown (7.5YR3/3) moist and brown (7.5YR4/4)  
dry; Sandy loam; soft when dry; weak single  
grained, fine crumb; non sticky, non plastic  
when wet; many very fine and fine, few medium  
pores; many very fine and fine roots; presence  
of few charcoal; abrupt and smooth boundary  
towards Bts1.

Bts1 5-38 cm: Dark redish brown (2.5YR3/4) moist and red  
(2.5YR4/6) dry; sandy clay; hard when dry;  
weak massive, sub-angular blocky; sticky and  
plastic when wet; many very fine and fine,  
few medium pores; few fine, few medium and  
few common roots; plent thin clay and  
sesquioxides, few charcoal; diffuse and

smooth boundary towards Bts2.

Bts2 38-88 cm Red (2.5YR4/6) moist and red (2.5YR5/8) dry; clay; moderate, medium to fine sub-angular blocky; sticky and plastic when wet; many very fine and fine, few medium pores; few fine, few medium, few common roots; clay and sesquioxides accumulation in the matrix; presence of few charcoal; clear and smooth boundary towards Bts3. Bts3 88-136 cm Red (2.5YR4/8) moist; clay; friable when moist; moderate, fine sub-angular blocky; slightly sticky and plastic when when wet; many very fine and fine pores; few fine, few medium roots; clay and sesquioxides accumulation in the matrix; diffuse and smooth boundary towards Bts4.

Bts4 135-185+ cm Red (2.5YR4/8) moist; clay; friable when moist; moderate, fine sub-angular blocky; slightly sticky and plastic when wet; many very fine and fine pores; few fine and few medium roots; clay and sesquioxides accumulation in the matrix.

**Pedon 3: Veyula - Makutupora = Thereafter referred to as  
DU3**

Date of description and sampling: 3/ 5/ 94

Authors: B.M.Msanya and G.M.R Budotela

Survey area / District: Veyula Makutupora/ Dodoma Capital  
City

Location: Mr. Haule's vineyard at Veyula-Makutupora, 6°  
0.2' 20" S and 35° 45' 23.5" E, 24 km from  
Dodoma towards Arusha, 150 m east of the Dodoma  
Arusha main road.

Classification: (Soil Survey Staff, 1990). Ustic

Torriorthents

(FAO-UNESCO, 1989). Dystric Regosols

Elevation: About 1118.9 masl

Geological formation: Neogene system comprising  
undifferentiated soils

Parent material: Alluvium/Colluvium derived from granitic  
rocks.

Landform: (i) Physiographic position: Foot slope  
(piedmont).

(ii) Surrounding landform: flat.

(iii) Slope on which the profile is situated:

1- 2% linear slope about 2600M in

length, positioned at upper quarter.

Rainfall: Annual rainfall varies from 500-700ml with an average of 500ml and a pronounced dry season ranging from 6-8 months.

Drainage: Well drained.

Moisture conditions in the profile: Moist below 155cm.

Soil moisture regime: Ustic \ Aridic

Soil temperature regime: Hyperthermic

Depth of ground water table: Too deep to affect the profile.

Presence of stoniness and rock outcrops: None.

Evidence of erosion: Slight to moderate splash, but without deposition at the site and adjacent fields.

Presence of salt or alkali: None.

Human influence: clearing and cultivation.

Vegetation: Mitunduru and Mahata shrubs.

#### **Description of individual horizons.**

Apm 0-23 cm Dark gley brown(10YR4/2) moist and brown (10YR5/3) dry; sandy clay; hard to very hard when dry; massive; slightly sticky and plastic when wet; many very fine and fine, few medium pores; many very fine and fine roots; few animal burrows; abrupt and smooth boundary towards AC1.

AC1 23-38 cm Dark yellowish brown (10YR4/4) moist and light yellowish brown (10YR6/4) dry; sandy clay; slightly hard when dry; massive slightly sticky and plastic when wet; many very fine and fine, few medium pores; common very fine and fine, few medium roots; gradual smooth boundary towards AC2.

AC2 38-65 cm Yellowish brown (10YR5/6) moist and yellow (10YR7/5) dry; clay; soft when dry; massive; slightly sticky and slightly plastic when wet; many very fine and fine, few medium pores; few very fine and fine roots; diffuse and smooth boundary towards AC3.

AC3 65-117 cm Yellowish brown (10YR5/6) moist and Yellow (10YR7/6) dry; clay; soft when dry; massive; slightly sticky and slightly plastic when wet; many very fine and fine, few medium and few coarse pores; few very fine and fine roots; diffuse and smooth boundary towards AC4.

AC4 117-155+ cm Yellowish brown (10YR5/5) moist; clay; friable when moist; massive; slightly sticky and slightly plastic when wet; many very fine and fine, few medium, few coarse pores; few very fine and fine, few medium roots.

Appendix 2.1 Some physico-chemical properties of profile No. DU1

Horizon	AP	AC1h	AC2	AC3	AC4
Depth(cm)	0-10	10-30/40	30/40-80	80-115	115-180*
<b>Particle size analysis(%)</b>					
sand	58.4	55.2	29.6	23.2	32.8
silt	12.8	6.4	8.0	9.6	6.4
clay	28.8	38.4	62.4	67.2	60.8
<b>Textural class</b>					
PH 1:2.5 (H <sub>2</sub> O)	SC 7.4	SC 5.7	SC 4.9	SC 4.3	SC 3.8
1:2.5 (KCl)	6.4	4.2	3.5	3.6	3.4
O.C. (%)	1.0	0.4	0.1	0.2	0.1
O.M. (%)	1.4	1.0	0.2	0.4	0.2
Total N (%)	0.1	0.3	0.1	0.1	0.1
Bray-1 P (ppm)	46.5	12.3	3.5	2.6	2.6
CEC (me/100g)	7.4	3.5	4.4	4.1	5.0
<b>Exchangeable bases</b>					
Ca <sup>2+</sup>	2.8	0.5	0.5	0.2	0.2
Mg <sup>2+</sup>	0.4	0.3	0.3	0.1	0.1
K <sup>+</sup>	1.1	0.6	0.6	0.4	0.5
Na <sup>+</sup>	0.2	0.2	0.2	0.2	0.2
Al <sup>3+</sup>	-	-	0.1	0.1	0.2
H <sup>+</sup>	-	-	0.1	0.1	0.1
<b>Summation of bases</b>					
	4.4	1.6	1.6	0.8	0.9
% BS	59.1	46.0	36.4	19.1	19.4

## Appendix 2.1 (Continues)

## Moisture retention characteristics

Depth (cm)	Top	50	100
Bulky density (g/cm <sup>3</sup> )	1.92	1.8	1.78
p <sup>F0</sup>	40.40	42.8	39.20
p <sup>F1</sup>	19.90	25.3	27.70
p <sup>F1.5</sup>	18.20	23.1	25.20
p <sup>F2</sup>	17.90	22.5	24.80
p <sup>F3</sup>	17.00	20.4	21.60
p <sup>F3.6</sup>	14.70	16.5	19.40
p <sup>F4.2</sup>	12.00	14.5	17.50
AWC	6.90	11.4	11.10

DU1 = Dodoma Urban profile No. 1

Appendix 2.2 Some physico-chemical properties of profile No. DU2

Horizon	AP	BtS1	BtS2	BtS3	BtS4
Depth (cm)	0-5	5-38	38-88	88-136	136-185'
<b>Particle size analysis(%)</b>					
sand	74.4	48.8	36.0	29.6	32.8
silt	16.0	6.4	8.0	6.4	9.6
clay	9.6	44.8	56.0	64.0	57.0
Textural class	SL	SC	C	C	SC
pH 1:2.5 (H <sub>2</sub> O)	8.2	7.7	4.4	4.4	4.2
1:2.5 (KCl)	7.2	6.0	3.6	3.5	3.4
O.C. (%)	0.4	0.2	0.2	0.1	0.1
O.M. (%)	0.6	0.4	0.4	0.2	0.2
Total N (%)	0.1	0.1	0.2	0.1	0.1
Bray-1 P (ppm)	3.5	5.3	1.8	2.6	1.8
CEC (me/100 g)	11.0	6.7	6.0	7.5	5.8
<b>Exchangeable bases:</b>					
Ca <sup>2+</sup>	5.0	1.7	0.3	0.4	0.3
Mg <sup>2+</sup>	0.7	0.6	0.2	0.2	0.2
K <sup>+</sup>	1.9	1.1	0.4	0.4	0.2
Na <sup>+</sup>	0.2	0.2	0.2	0.2	0.3
Al <sup>3+</sup>	-	-	0.1	0.1	0.1
H <sup>+</sup>	-	-	0.2	0.1	0.1
<b>Summation</b>					
of bases	7.8	3.5	1.1	1.2	1.0
% B.S.	71.2	51.9	16.4	16.0	16.4

Appendix 2.2 (Continues)  
Moisture retention characteristics

Depth (cm)	Top	50	100
Bulky			
density (g/cm)	2.45	1.83	1.82
$p^{F0}$	44.8	37.1	37.1
$p^{F1}$	29.9	21.9	26.0
$p^{F1.5}$	27.8	20.0	24.3
$p^{F2}$	27.4	19.9	17.0
$p^{F3}$	26.3	17.5	14.1
$p^{F3.6}$	24.9	16.1	10.2
$p^{F4.2}$	21.2	11.6	7.6
AWC	7.7	8.9	13.7

DU2 = Dodoma urban profile No. 2

## Appendix 2.3 Some physical-chemical properties of profile DU3

Horizon	APM	AC1	AC2	AC3	AC4
Depth (cm)	0-23	23-38	38-65	65-117	117-155'
<b>Particle size analysis(%)</b>					
sand	48.8	45.6	36.0	26.4	20.0
silt	8.0	6.4	6.4	9.6	12.8
clay	43.2	48.0	57.6	64.0	67.2
<b>Textural</b>					
class	SC	SC	C	C	C
<b>pH 1:2.5</b>					
(H <sub>2</sub> O)	6.1	4.9	5.0	4.7	3.9
<b>pH 1:2.5</b>					
(KCl)	4.3	3.9	4.0	3.6	3.3
O.C. (%)	0.46	0.12	0.23	0.35	0.35
O.m. (%)	0.80	0.20	0.40	0.60	0.60
<b>Total</b>					
N (%)	0.04	0.01	0.02	0.03	0.03
<b>Bray-1</b>					
P (ppm)	20.18	3.51	3.51	3.51	3.51
(me/100 g)	8.00	10.72	8.16	12.00	8.96
<b>Exchangeable bases</b>					
<b>(me/100g)</b>					
Ca <sup>2+</sup>	0.80	0.30	0.30	0.30	0.3
Mg <sup>2+</sup>	0.33	0.03	0.03	0.10	0.26
K <sup>+</sup>	0.90	0.38	0.38	0.72	0.27
Na <sup>+</sup>	0.15	0.15	0.22	0.15	0.15
Al <sup>3+</sup>	-	0.01	0.02	0.01	0.02
H <sup>+</sup>	-	0.01	trace	0.01	trace
<b>Summation</b>					
of Bases	2.18	0.86	0.93	1.27	0.98
% BS	27.25	8.05	11.43	10.575	10.94

## Appendix 2.3 continue

## Moisture retention characteristics

Depth (cm)	Top	50	100
Bulky density (g/cm <sup>3</sup> )	2.03	1.82	1.59
p <sup>F0</sup>	30.4	39.8	42.2
p <sup>F1</sup>	18.0	26.9	31.0
p <sup>F1.5</sup>	16.2	19.4	28.6
p <sup>F2</sup>	15.8	19.3	27.8
p <sup>F3</sup>	14.2	19.2	25.0
p <sup>F3.6</sup>	10.8	16.8	21.2
p <sup>F4.2</sup>	9.4	13.8	6.2
ACW	3.7	10.9	15.5

### Appendix 3 Meteorological data of the grape growing study area

	Jan	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
<b>Rainfall</b>													
<b>(mm)</b>													
1993	200	148	150	0	0	0	0	0	0	0	10	8	516
1994	216.8	147.0	179	0	0	0	0	0	0	0	0	0	542.8
<b>Rainfall distribution (number of days)</b>													
1993	10	9	12								1	1	33
1994	8	11	10	0	0	0	0	0	0	0	0	0	29
<b>Temperature (° C)</b>													
<b>1993</b>													
Mean max.	36.3	38.3	39.8	35.3	32.8	30.8	30.3	37.1	32.3	33.8	36.3	37.3	420.4
Mean min.	9.8	12.3	8.0	6.3	5.3	4.8	8.8	10.8	15.5	17.7	19.51	20.0	138.8
<b>1994</b>													
Mean max.	32.55	34.0	35.0	34.5	32.4	30.6	-	-	-	-	-	-	-
Mean min.	19.88	18.63	20.0	15.0	8.0	5.0	-	-	-	-	-	-	-

Source: Viticultural Research and Training Centre Makutupora

**Appendix 4: Changes in NaOH extractable P in soils over 90 days following addition of 500 mg P kg<sup>-1</sup>**

Sample	Material	Time in days								
		0	7	14	30	45	60	75	90	
	TSP	178.56	328.32	328.28	328.32	328.32	303.20	287	285	
MA	MPR	17.28	74.88	93.24	146.00	310.48	310.00	311	310	
	TSP	161.28	334.08	334.08	334.08	334.08	309.04	289	280	
MM	MPR	4.24	58.00	90.32	150.88	259.20	259.20	259	260	
	TSP	264.96	311.04	371.64	311.04	311.04	301.00	290	285	
VH	MPR	28.80	46.08	98.56	101.04	213.12	213.12	214	213	