CHAPTER 2

EFFECT OF NITROGEN NUTRITION ON THE GROWTH AND YIELD OF WILD GINGER

2.1 Introduction

Nitrogen is a major essential nutrient element required by plants in substantial quantities. It is the constituent of proteins and many metabolic intermediates involved in synthesis and energy transfer, and of nucleic acids (Goh & Haynes, 1986; Mengel & Kirkby, 1987). Numerous workers viewed it as the control element because of its role in the production of certain substances, such as protein and nucleic acids that form the living material (Novoa & Loomis, 1981). The authors stressed that it is also commonly the most limiting plant nutrient for crop production in the majority of the world's agricultural areas. Therefore, adoption of good N management strategies often results in large economic benefits to farmers.

Nitrogen is the only plant nutrient which can be added to the soil by biological nitrogen fixation (BNF), but for many cropping systems in the tropics, addition of nitrogen through BNF is insufficient to cover the loss of nitrogen with crop removal, leaching and denitrification (Olson & Kurtz, 1982). The authors reported that when the supply of soil water is adequate, N is the most limiting factor for crop production. Thus, on the average considerable more N than any other element is supplied to crops as fertilizer and is removed from agricultural lands in harvested crops.

No work was done on the effect of nitrogen nutrition on the growth and yield of wild ginger, however the study was undertaken to determine the effect of nitrogen nutrition on the growth and yield of wild ginger under field conditions.

2.2 Materials and methods

2.2.1 Location

The experiment was conducted at the University of Pretoria's Hatfield Experimental Farm, South Africa in the summer (December) of 2001. The area is at an altitude of 1370 m with annual rainfall of 600-700 mm. The soil type of the experimental area was a sandy loam. Before the experiment was established, the fertility status of the soil was determined (Appendix B). Samples were analysed at the Soil Science Laboratory in the University of Pretoria for P, K, Mg, Ca, Na and pH (soil analysis package) using ammonium acetate extractable method. Soil samples were taken from both topsoil (0-15 cm) and subsoil (15-30 cm) with an auger.

3.2.2 Design

The experiment was designed according to a systematic, non-replicated design to establish response curves from mini plots for wild ginger. The gross plot size was 26 m^2. Plant spacing were 0.3m within a row and 0.5m between the rows. Plant population was 66 667 plants ha^{-1}.

2.2.3 Treatments

Six levels of nitrogen viz. 0, 50, 100, 150, 200, and 250 $kg \cdot ha^{-1}$N designated (N1, N2, …N6) were used and all was applied at planting. The source of nitrogen was limestone ammonium nitrate (28% N).

3.2.4 Planting material

Mature rhizomes of varying sizes (circumferences of 2-3 cm) were used and were obtained from the CSIR. Rhizome circumference was measured using vernier callipers (Switzerland) in order to obtain rhizomes of similar sizes and mass was determined using a measuring scale (Oerting, UK). Circumference details of each rhizome planted were recorded and each one kept in a separate netting bag. Before planting, rhizomes were dipped in a solution of copper oxy-chloride (5 g in 10 L water) to prevent soil borne diseases. Each rhizome was planted in a shallow hole of about 5 cm depth. Water was applied immediately after planting by sprinkler irrigation for 3 hours to aid in rhizome establishment. Thereafter, irrigation was applied twice every week (Tuesdays and Fridays). Weeds were eradicated by hand as soon as they were noticed.

2.2.5 **Records**

Emergence of the plants was recorded up to 140 days after planting (DAP) and plant height was recorded at 168 DAP. Number of leaves, fresh and dry leaf mass and leaf area was not recorded as the leaves wilted due to harsh winter environment before the final harvest. Yield in terms of fresh rhizome and enlarged root mass, fresh rhizome circumference, length of enlarged roots and the number of rhizomes and enlarged roots were recorded during the final harvest at 206 DAP.

2.2.6 **Data**

The data was analysed using the general linear model (GLM) procedure within the SAS computer software (SAS Institute, Inc., 1996).

2.3 **Results and Discussion**

2.3.1 **Plant emergence**

Wild ginger plants emerged very late. Emergence began 56 days after planting (DAP). Similarly, Wilson & Ovid (1993) detected that the germination of ginger began after 56 DAP. This was also in agreement with the results found by Lee, Edwards & Asher (1981), where good uniform emergence was obtained 50 DAP. Emergence at different N levels was slow during the initial growth stages and at later growth stages more plants emerged in different treatments. At 140 DAP, emergence of the plants stopped at all levels of nitrogen. Plants that received 250 $kg \cdot ha^{-1}$ N had more plant emergence as compared to all other N levels followed by plants that received 50 $kg \cdot ha^{-1}$ and the least was where plants received no nitrogen. In general, emergence of the plants was very poor due to the fact that plants were planted while the rhizomes had already sprouted and some of the sprouts dried off before planting. This brought the practice of timely planting of wild ginger rhizomes as an utmost important variable. Plants that received no nitrogen and 100 $kg \cdot ha^{-1}$, through visual inspection, had stunted growth at 168 DAP with an average plant height of about 8.44 cm with reduced tillers (Table 2.1). However, plants that received 50, 150, 200 and 250 kg·ha^{-1} respectively showed good crop growth and had greater number of tillers (Table 2.1).

There was no data collected for the shoots since the plants suffered early senescence as the plants approached harsh winter environments due to delayed planting. With respect to true ginger (*Zingiber officinale*), planting occurs from late August to mid October, with the optimum period being mid to late August (Broadley, 2003). No flowering data was recorded. Broadley (2003) reported that wild ginger can produce 25-30 flowers during November and early December when planted during the appropriate planting period (August to early September).

2.3.2 **Yield**

2.3.2.1 **Fresh rhizome mass**

The results of this experiment are presented in Figures 2.1 to 2.6 and Appendix A. Yields were generally poor across nitrogen levels. However, this might be attributed to the fact that all nitrogen was applied during planting and this might have caused the sprouts of rhizomes beneath the soil to be burnt, leading to poor emergence which subsequently affected the final yield of wild ginger. Broadley (2003) stated that 20% of the nitrogen should be applied between germination and December and the remaining 80% should be applied in 7 to 10 applications between early January to April.

There was a positive linear relationship between fresh rhizome mass and applied nitrogen (Fig. 2.1). Where plants received no nitrogen, the yield was 0.65 g and 3.6 g at the highest N level (250 kg·ha^{-1}). Fresh rhizome mass increased by 0.01 g per unit increase in N application levels.

Table 2.1 Effect of N fertilizer applications on the growth of wild ginger

Nitrogen ($kg \cdot ha^{-1}$)	Days after planting (DAP)	Average number of tillers per treatment	Average root length (mm)	Average number of enlarged roots	Average number of rhizomes	Mean plant height (cm)
0	120	1	-----	-----	-----	8.44
	150	2	-----	-----	-----	-----
	206	2	35	16	1.2	-----
50	120	2	-----	-----	-----	11.72
	150	3	-----	-----	-----	-----
	206	3	49	25	2.8	-----
100	120	1	-----	-----	-----	9.53
	150	2	-----	-----	-----	-----
	206	2	38	17	2.1	-----
150	120	2	-----	-----	-----	11.65
	150	3	-----	-----	-----	-----
	206	3	39	22	2.2	-----
200	120	3	-----	-----	-----	14.75
	150	4	-----	-----	-----	-----
	206	4	53	13	2.6	-----
250	120	4	-----	-----	-----	13.3
	150	4	-----	-----	-----	-----
	206	4	46	38	3.7	-----

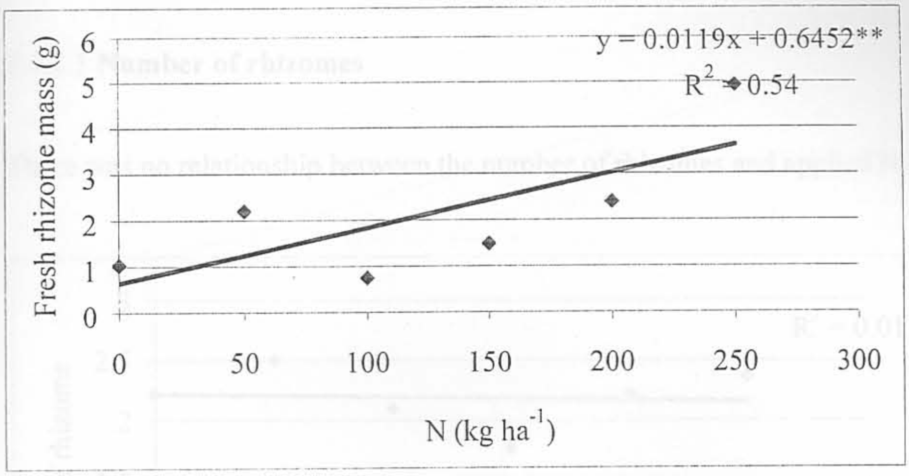

Fig. 2.1 Relationship between fresh rhizome mass and six N levels during 2001/02 growing seasons

2.3.2.2 **Fresh rhizome circumference**

There was a strong positive linear relationship between the fresh rhizome circumference and the applied nitrogen (Fig. 2.2). Plants that received the highest N level (250 kg·ha^{-1} N) resulted in fresh rhizome circumference of 19.2 mm and there was rhizome circumference of 11.1 mm where no nitrogen was applied. For each increase in N application rate, fresh rhizome circumference increased with 0.03 mm.

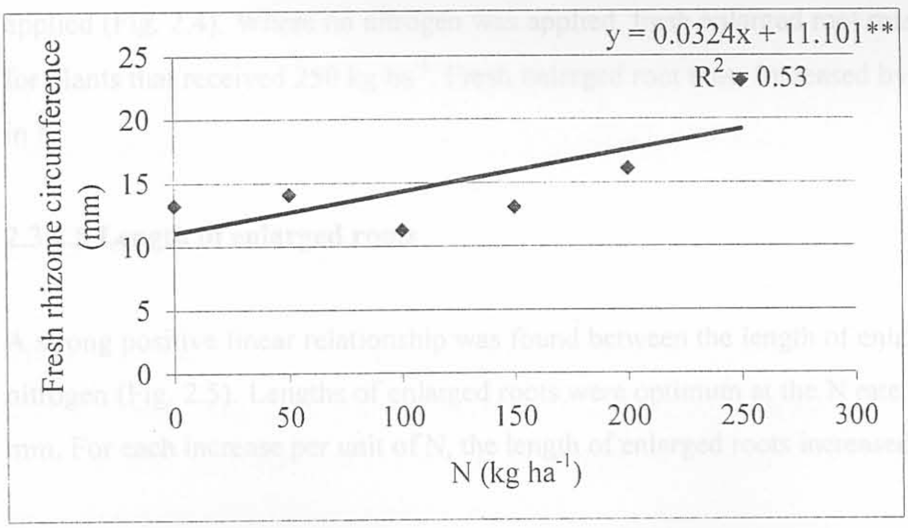

Fig. 2.2 Fresh rhizome circumference as affected by six nitrogen levels during 2001/02 seasons

2.3.2.3 **Number of rhizomes**

There was no relationship between the number of rhizomes and applied N (Fig. 2.3).

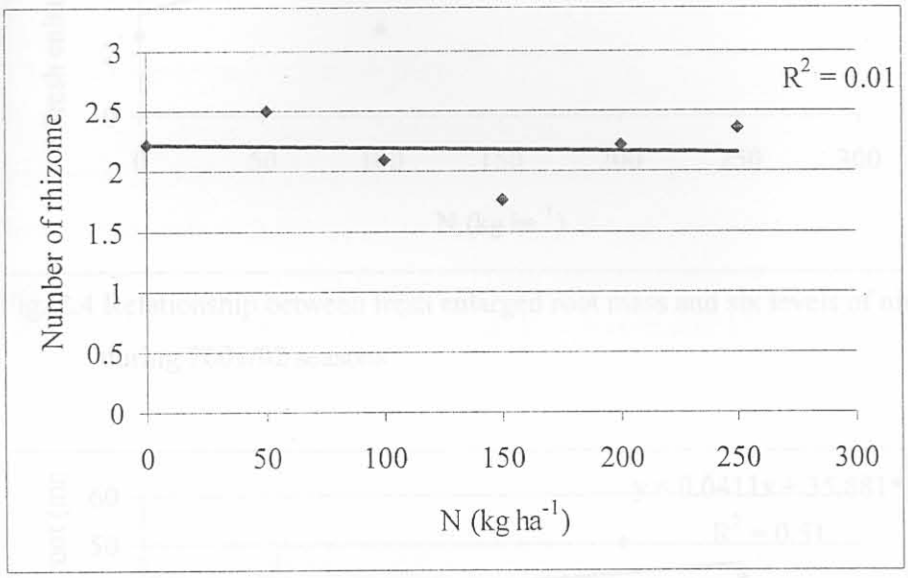

Fig. 2.3 Number of rhizomes as affected by six N levels during 2001/02 seasons

2.3.2.4 **Fresh enlarged root mass**

There was a strong positive linear relationship between fresh enlarged root mass and nitrogen applied (Fig. 2.4). Where no nitrogen was applied, fresh enlarged root mass was 3.3 g and 8.6 g for plants that received 250 kg·ha^{-1}. Fresh enlarged root mass increased by 0.02 per unit increase in N.

2.3.2.5 **Length of enlarged roots**

A strong positive linear relationship was found between the length of enlarged roots and applied nitrogen (Fig. 2.5). Lengths of enlarged roots were optimum at the N rate of 200 kg·ha^{-1} with 44 mm. For each increase per unit of N, the length of enlarged roots increased with 0.04 mm.

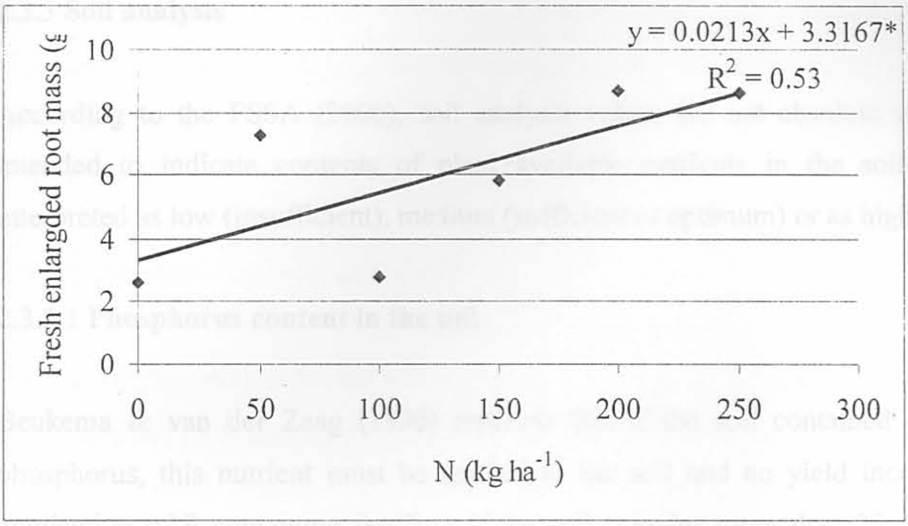

Fig. 2.4 Relationship between fresh enlarged root mass and six levels of nitrogen during 2001/02 seasons

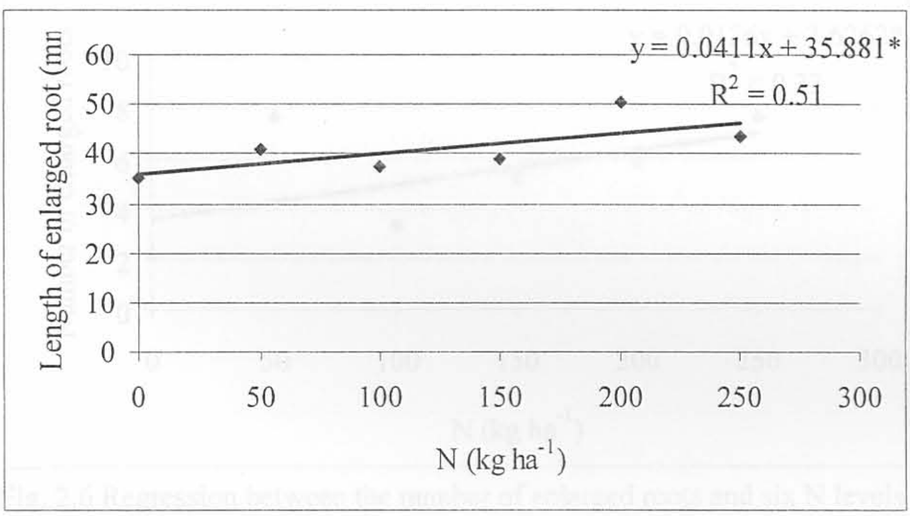

Fig. 2.5 Length of enlarged root as affected by six N levels during 2001/02 seasons.

2.3.2.6 Number of enlarged roots

There was weak positive linear relationship between applied nitrogen and the number of enlarged roots (Fig. 2.6). Plants that received 250 kg·ha^{-1} had the highest number of enlarged roots (7) and an average of (4) where no nitrogen was applied. Average number of enlarged roots increased with 0.01 per unit increase in N.

2.3.3 **Soil analysis**

According to the FSSA (2000), soil analysis values are not absolute values. They are only intended to indicate contents of plant available nutrients in the soil. However, they are interpreted as low (insufficient), medium (sufficient or optimum) or as high (too high).

2.3.3.1 **Phosphorus content in the soil**

Beukema & van der Zaag (1990) reported that if the soil contained less than 15 ppm of phosphorus, this nutrient must be applied to the soil and no yield increase will result from application of P containing fertilizer if the soil contains more than 25 ppm and according to FSSA (2003), P content in the soil for potato is optimum at 30 to 60 ppm.

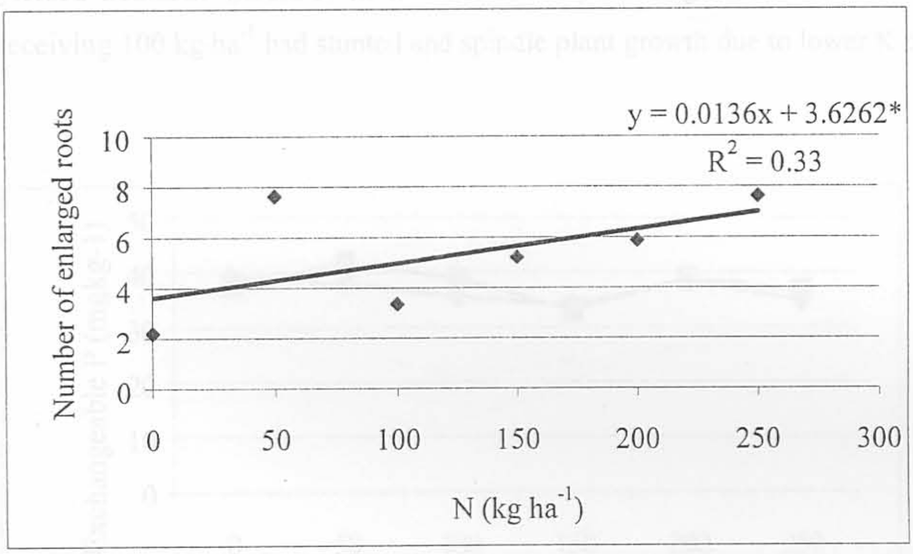

Fig. 2.6 Regression between the number of enlarged roots and six N levels during 2001/02 seasons

For both subsoil and topsoil, P content in the soil was higher than 25 ppm and P content was higher in the subsoil than in the topsoil (Fig. 2.7). P content was not limiting rather too much in the soil, therefore any application of P was not going to result in increased yield of wild ginger. For the topsoil and the subsoil , plants receiving no nitrogen resulted in maximum P and the least was observed for plots fertilized with 150 kg·ha^{-1} whereas for the subsoil, plots fertilized with 50 kg·ha^{-1} resulted in maximum P content and the least was obtained in plots receiving 150 kg·ha^{-1}.

P has been reported to increase yield and the number of tubers. Plants fertilized with 50 kg·ha^{-1} N resulted in superior yield and higher average number of rhizomes than plants receiving 0, 100, 150 and 200 kg·ha^{-1}. This might be attributed to the fact that they contained more P content which resulted in increased yield.

2.3.3.2 **Potassium content in the soil**

For the topsoil, plots fertilized with 250 kg·ha^{-1} N resulted in the highest K content and the least was found for plots fertilized with 100 kg·ha^{-1}(Fig. 2.8). For the subsoil, plots fertilized with 50 kg·ha^{-1} resulted in the superior K and the least was found at 100 kg·ha^{-1}. Plots fertilized with 50 and 250 kg·ha^{-1} resulted in maximum yield whereas plots fertilized with 100 kg·ha^{-1} was the least yielded treatment across N levels. The lower yield might be attributed to the fact that plants receiving 100 kg·ha^{-1} had stunted and spindle plant growth due to lower K content.

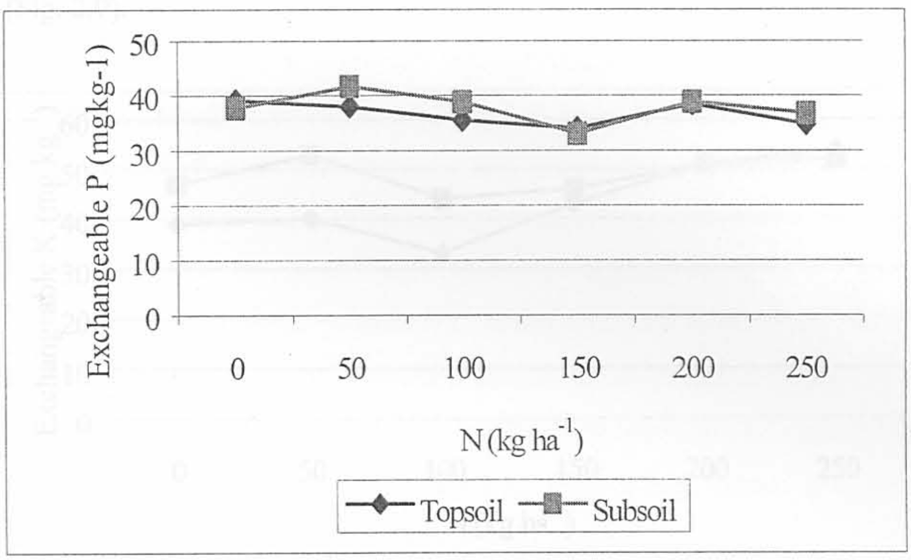

Fig. 2.7 P content in the soil as affected by six N levels

2.3.3.3 **Soil pH**

Application of N treatments affected the pH of the soil. For the topsoil, soil pH was neutral to slightly alkaline at plots that received 0, 50, 100 and 150 kg·ha^{-1} and acidic at 200 and 250 kg·ha^{-1} whereas for the subsoil, soil was acidic across the six N levels (Fig. 2.9). For the topsoil, plots fertilized with 100 kg·ha^{-1} had a soil pH of slightly alkaline to neutral and resulted in poor yield. Broadley (2003) found that in normal soils at the pH of acidic to neutral (6.5 to 7.0), higher true ginger (*Zingiber officinale*) yields are obtained and if low, soil pH correction should be done approximately six weeks before planting.

Plants fertilized with 250 kg·ha^{-1} N resulted in maximum yield and this was apparent as plants at that N application level was at medium acidity, which is the soil pH at which wild ginger crops are adapted. Similarly, for the subsoil, plants which performed better had their soil pH values of acidic to neutral, which are also best pH medium for wild ginger growth and significant yielding. Plants that received 200 and 250 kg·ha^{-1} also resulted in superior yield at the pH of 6.4 (Fig. 2.9).

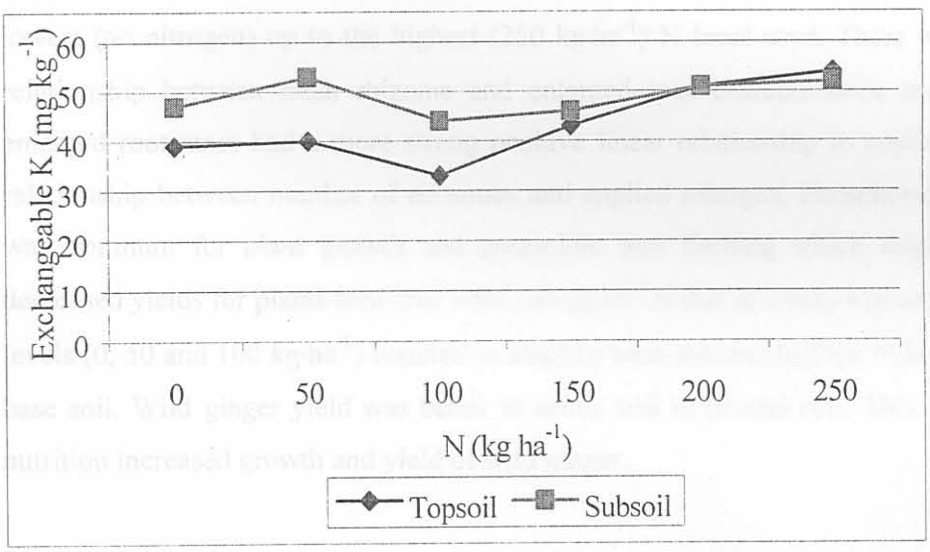

Fig. 2.8 Potassium content in the soil as affected by six levels of N

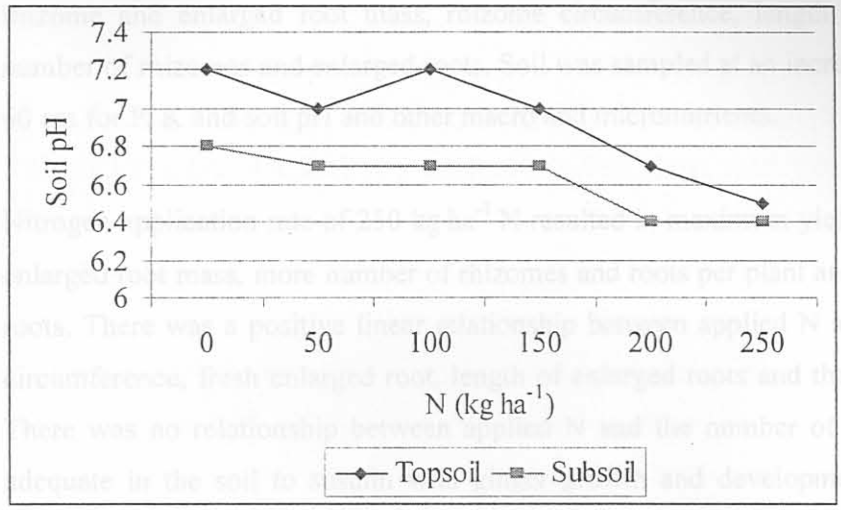

Fig. 2.9 Soil pH as affected by the application of six N levels

2.4 Conclusions

Plants that received 0 and 100 kg·ha^{-1} N had poor stand establishments which subsequently reduced yield. A final conclusion was not reached as to which N level was optimal for fresh rhizome and enlarged root characteristics because the results showed a linear increase from the lowest (no nitrogen) up to the highest (250 kg·ha^{-1}) N level used. There was a positive linear relationship between fresh rhizome and enlarged root characteristics and applied N. Fresh enlarged root mass had a more strong positive linear relationship to applied N. There was no relationship between number of rhizomes and applied nitrogen. Phosphorus content in the soil was optimum for plant growth and potassium was limiting which might have resulted in decreased yields for plants fertilized with 100 kg·ha^{-1} N due to a very low amount of K. Lower N levels (0, 50 and 100 kg·ha^{-1}) resulted in alkaline base soil and highest N levels exhibited acidic base soil. Wild ginger yield was better in acidic soil to neutral soil. This study reveals that N nutrition increased growth and yield of wild ginger.

2.5 Summary

A field trial was carried out on wild ginger on a sandy loam soil at the University of Pretoria's Hatfield Experimental Farm. Treatment used were six levels of nitrogen rates (0, 50, 100, 150, 200 and 250 kg·ha^{-1}) and it was all broadcasted at planting. Measurements were made of fresh rhizome and enlarged root mass, rhizome circumference, length of enlarged roots and the number of rhizomes and enlarged roots. Soil was sampled at an increment of 0 - 30 cm and 30 – 60 cm for P, K and soil pH and other macro and micronutrients.

Nitrogen application rate of 250 kg·ha^{-1} N resulted in maximum yield for the fresh rhizome and enlarged root mass, more number of rhizomes and roots per plant and greater length of enlarged roots. There was a positive linear relationship between applied N and fresh rhizome mass and circumference, fresh enlarged root, length of enlarged roots and the number of enlarged roots. There was no relationship between applied N and the number of rhizomes. Phosphorus was adequate in the soil to sustain wild ginger growth and development whereas potassium was limiting. Application of N affected soil pH. Nitrogen application levels of 0, 50 and 100 resulted in the acidity of soil and 150, 200 and 250 N levels resulted in the alkalinity of the soil. This study demonstrated N nutrition increased growth and yield of wild ginger.