GENERAL DISCUSSION AND CONCLUSIONS

An experiment was conducted in the field to determine the response of wild ginger growth and yield to nitrogen nutrition. Planting materials used were sprouted wild ginger rhizomes obtained from the Centre of Scientific and Industrial Research (CSIR). Treatments used were six levels of nitrogen (0, 50, 100, 150, 200 and 250). All N treatments were applied at planting in the form of limestone ammonium nitrate (LAN). Measurements were made of plant emergence, plant height, fresh rhizome and enlarged root, fresh rhizome circumference, length of enlarged root and the number of rhizomes and enlarged roots. N level of 200 kg·ha^{-1} was effective in increasing wild ginger plant height and 250 kg·ha^{-1} was effective in increasing plant emergencies. There was a positive linear relationship in all yield parameters except for the number of rhizomes per plant which had shown a no relationship to applied nitrogen. In this study, in terms of yield, it was not clear which N level was optimum, since the trend have shown an increased up to the highest N treatment applied (250 kg·ha^{-1}).

A tunnel study was undertaken to determine the influence of fertigation frequency and growing medium on the growth, oil quality and yield of wild ginger. Treatments used were five fertigation frequencies (0.25L/day, 1L/day, 2L/day, 2L/2nd day and 2L/week) and two growing media (Pine bark and sand). Measurements were made of plant growth such as plant height, number of leaves and stem at 56, 112, 168 and 224 days after emergence (DAE) and fresh and dry leaf mass and leaf area at 112 and 224 DAE. Yield such as fresh and dry rhizomes mass, fresh and dry enlarged root mass, length of enlarged roots and the number of rhizomes and enlarged roots.

Wild ginger growth was reduced with a fertigation frequency of 2L/day during initial growth stages (56 DAE) and at later stages of development (112, 168 and 224 DAE), a fertigation frequency of 2L/week was inadequate to sustain wild ginger growth and development. Plants grown in pine bark have shown improved growth during the initial growth stages (56 and 112 DAE) and at later stages of growth, plants grown in sand have shown an increased in wild ginger growth and development. Fertigation frequency of 1L/day improved fresh and dry leaf mass and plants grown in pine bark increased fresh and dry leaf mass at 112 and 224 DAE. Greater leaf areas were improved when fertigated with 2L/2nd day at 112 and 224 DAE.

However, plants grown in pine bark improved leaf area at 112 DAE and at 224 DAE, wild ginger leaf area were improved with plants grown in sand.

Although there were differences in wild ginger growth and development, fertigation frequency as well as growing medium did not affect yield at 112 DAE. Number of enlarged roots were increased when wild ginger plants were fertigated with 1L/day at 112 DAE and 2L/day at 224 DAE. Plants grown in pine bark increased number of enlarged roots at 112 DAE and those grown in pine bark improved the number of enlarged roots at 224 DAE. Fertigation frequency s well as growing medium did not affect the number of rhizomes and enlarged roots at both 112 and 224 DAE. Wild ginger fresh rhizomes was increased when fertigated with 2L/2nd day at 224 DAE and fresh enlarged root yield was increased when fertigated with 2L/day at 224 DAE. Fertigation frequency as well as growing medium did not affect fresh rhizome and enlarged root oil yield at 224 DAE. Response of wild ginger growth and yield to fertigation frequency and growing medium is highly depended on different sampling dates.

Two experiments were conducted in a Laboratory at the Department of Plant Production and Soil Science, University of Pretoria to determine the effect of nitrogen nutrition and the effect of fertigation frequency and growing medium on the enlarged root anatomy of wild ginger. Wild ginger plants were grown in pine bark under a glasshouse for the anatomy study of enlarged roots as affected by N application levels and for the effect of fertigation frequency and growing medium, plants were grown in sand and pine bark. Treatments used were six levels of nitrogen viz. 0, 50, 100, 150, 200 and 250 $kg \cdot ha^{-1}$, five fertigation frequency (0.25L/day, 1L/day, 2L/day, 2L/2nd day and 2L/week) and growing media used were pine bark and sand.

Plants were harvested at 224 days after emergence (DAE) for sectioning thereafter, enlarged roots were immersed in small test tubes and fixed in a solution of F.A.A [(100 ml acetic acid (CH_3COOH), 100 ml formaldehyde (HCHO) and 1800 ml 50% ethanol (CH_2H_2OH), thereafter were put on a mechanical shaker for 2 to 3 hours. Samples were dehydrated with 30, 50, 70 and 100% ethanol and ethanol was extracted from the samples at 30, 50, 70 and 100% xylene. Samples were mounted so that they could be preserved for years and stained with toluidine solution. Anatomical structures of wild ginger enlarged root were observed with a light microscope at 100X magnification. Anatomical structures observed in wild ginger enlarged roots were primary xylems and the cells between them, glandular cells, pericycle layer, cortex, endodermis and pith.

N application levels increased the number of glandular cells, important for the production of essential oil. Glandular cells increased from one where no nitrogen was applied to eight where the highest level (250 $kg \cdot ha^{-1}$) was used. N application rates also increased the number of primary xylems, the size of the pith and endodermis. Enlarged roots from all the nitrogen treatments had a single pericycle layer, a thick endodermis, and a large cortex containing starch grains. In all the treatments, there were 10 cells between the primary xylems.

For plants grown in pine bark, a fertigation frequency of 1L/day increased the number of glandular cells in wild ginger enlarged roots. Fertigation frequency also had improved number of primary xylems and cells between them and the size of the endodermis and cortex. There were no starch grains present in all fertigation frequencies applied. With plants grown in sand, a the lowest frequent fertigation (2L/week) improved the number of glandular cells, indicating improved capacity for production of essential oils by wild ginger roots. There were no starch grains present in all fertigation frequencies applied.

GENERAL SUMMARY

The valuable role of wild ginger as an important medicinal and aromatic plant has been known for decades by traditional practitioners. The effect of nitrogen on growth and medicinal value of wild ginger is, however, not known. A field trial on a sandy loam soil was established to determine the response of wild ginger growth and yield to nitrogen nutrition. Treatments used were six levels of nitrogen (0, 50, 100, 150, 200 and 250). All N treatments were applied at planting in the form of limestone ammonium nitrate (LAN). Measurements were made of plant emergence, plant height, fresh rhizome and enlarged root, fresh rhizome circumference, length of enlarged root and the number of rhizomes and enlarged roots. Nitrogen application level of 200 $kg{\cdot}ha^{-1}$ was effective in increasing wild ginger plant height and 250 $kg{\cdot}ha^{-1}$ was effective in increasing plant emergencies. There was a positive linear relationship in all yield parameters except for the number of rhizomes per plant which had shown a no relationship to applied nitrogen. It is recommended that wild plants should be fertilized with highest N (250 $kg{\cdot}ha^{-1}$) level to increase its growth and yield.

Fertigation may usher solution with water use efficiency in the range of 70-95% and improvement in crop yields by approximately 25% at a lesser cost. Also fertigation helps in improving the quality of produce, which could fetch better price both in domestic and overseas markets. However, the response of fertigation frequency and growing medium to wild ginger growth and development, oil quality and yield was not known. Hence, a tunnel study was undertaken to determine the influence of fertigation frequency and growing medium on the growth, oil quality and yield of wild ginger. Treatments used were five fertigation frequencies (0.25L/day, 1L/day, 2L/day, 2L/2nd day and 2L/week) and two growing media (pine bark and sand). Measurements were made of plant growth such as plant height, number of leaves and stem at 56, 112, 168 and 224 days after emergence (DAE) and fresh and dry leaf mass and leaf area at 112 and 224 DAE.

All fertigation frequencies increased wild ginger plant growth and development except with a fertigation frequency of 2L/day during the initial growth stages (56 DAE) and a fertigation frequency of 2L/week reduced plant growth during later stages of development (112, 168 and 224 DAE). Growths of plants grown in pine bark were improved during initial sampling dates (56 and 112 DAE) and at later sampling dates (168 and 224 DAE) growths of plants grown in sand were improved. At both initial (112 DAE) and later sampling dates (224 DAE) fresh and dry leaf were increased when fertigated with 1L/day, whereas leaf area was improved with a fertigation frequency of 2L/2[nd] day.

Yield was determined at 112 and 224 DAE and parameters measured were fresh and dry rhizomes mass, fresh and dry enlarged root mass, length of enlarged roots and the number of rhizomes and enlarged roots. Although, wild ginger plant growth showed differences in growth, fertigation frequency as well as growing medium did not affect the yield of fresh rhizome and enlarged root at 112 DAE. At 224 DAE, a fertigation frequency of 0.25L/day increased fresh rhizome mass and a fertigation frequency of 2L/day increased the yield of fresh enlarged root. At both 112 and 224 DAE, fresh rhizome and enlarged root were not affected by either pine bark or sand.

Fertigation frequency and growing medium did not affect the length of enlarged roots and the number of rhizomes. To increase the number of enlarged roots it was wised to fertigate plants with 2L/2[nd] day at 112 DAE as well as at 224 DAE.Fresh rhizome and enlarged root oil yield were not affected by fertigation frequency and growing medium.

During the initial sampling date (56 DAE), exceptionally a fertigation frequency of 2L/day is not recommended to improve wild ginger growth in that plants are still developing roots and unable to utilized too much fertigation supplied to them and at later sampling dates (112, 168 and 224 DAE) as well, a fertigation frequency of 2L/week is not recommended to improve wild ginger growth in that plants were big, therefore required more rather adequate fertigation to improve their growth. Wild ginger plants should be grown in pine bark during initial growth stages (56 and 112 DAE) and at later stages of growth (168 and 224 DAE) should be produced in sand. For the production of fresh rhizome yield, wild ginger plants should be fertigated with 2L/2[nd] day and for the fresh enlarged root yield, plants should be fertigated with 2L/day at later stages of growth. Either pine bark or sand is recommended to produce yield of wild ginger at initial as well as later stages of development.

An experiment was conducted in a Laboratory at the Department of Plant Production and Soil Science, University of Pretoria to determine the effect of nitrogen nutrition on the enlarged root anatomy of wild ginger. Plants were grown in pine bark under a glasshouse Treatments used were six levels of nitrogen viz. 0, 50, 100, 150, 200 and 250 kg·ha^{-1}. Enlarged roots for the N nutrition study as well as the fertigation frequency and growing medium study were harvested at 224 days after emergence (DAE) for sectioning thereafter, enlarged roots were immersed in small test tubes and fixed in a solution of F.A.A [(100 ml acetic acid (CH_3COOH), 100 ml formaldehyde (HCHO) and 1800 ml 50% ethanol (CH_2H_2OH), thereafter were put on a mechanical shaker for 2 to 3 hours. Samples were dehydrated with 30, 50, 70 and 100% ethanol and ethanol was extracted from the samples at 30, 50, 70 and 100% xylene. Samples were mounted so that they could be preserved for years and stained with toluidine solution. Anatomical structures of wild ginger enlarged root were observed with a light microscope at 100X magnification. Anatomical structures observed in wild ginger enlarged roots were primary xylems and the cells between them, glandular cells, pericycle layer, cortex, endodermis and pith.

N application level of 250 kg·ha^{-1} increased the number of glandular cells in the anatomy of wild ginger enlarged root, indicating improved capacity for production of essential oils by wild ginger roots. Glandular cells increased from two for plants that received no nitrogen to eight for plants that was fertilized with 250 kg·ha^{-1}. Glandular cells increased from two for plants that received no nitrogen to eight at the highest (250 kg·ha^{-1}) level applied. This study demonstrated that N nutrition is important for increasing glandular cells important for essential oil production.

For plants grown in pine bark, glandular cells increased from one for plants that received 0.25L/day to three for plants that received 1L/day, indicating improved capacity for production of essential oils by wild ginger roots. For plants grown in sand, there were no glandular cells for plants that received 2L/day and increased to sixteen when 2L/week was applied.

Further studies need to be implemented on the effect of N nutrition to the enlarged root anatomy of wild ginger, to determine clear relationships between the number of primary xylems, cells between primary xylems and the optimum N level which could results in the superior number of glandular cells. In this study, the highest N level (250) produced more glandular cells, therefore more N level need to be added in order to determine the optimum N level which will significantly increased the number of glandular cells. It is also recommended that, if one needs to grow wild ginger in pine bark, plants should be fertigated with 1L/day to increase the number of glandular cells essential for oil production, whereas in sand, a fertigation frequency of 2L/week should be used to increased the number of glandular cells.