



Effect of nutrient regime on patterns of resource allocation in *Phaseolus vulgaris* L. (kidney bean)

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Abstract:

Common bean is an important component of the production systems and a major source of protein. Nutrient solution concentration is a critical factor affecting plant growth in soil. Here, we investigated the effects of Nutrient solution on the growth and *Phaseolus vulgaris* L. (kidney bean) plants. First, were cultivated soil in two different nutrient with low, high concentrations and distilled water as control (0.0; 1.375, 22mM). Shoot and root length yield increased at (final week) days after plantation (DAP) of shoot and decreases of root length of bean, we examined the effect of nutrient changes of the cultivation period on the growth using high and low nutrient conditions. In plants transferred from high to low, the number of attached leaves increased toward the end of the first week of the cultivation period. Whereas this value increased in leaf length on concentration of high nutrient 22mM and decreases in concentration of lower 1.375mM of nutrient regime. The density of hairs showed on adaxial and abaxial leaf surface not significant difference between them. Our results suggest that the regulation of nutrient regime during the cultivation period affects the growth characteristics of bean. The effect of nutrient on fresh and dry weight of shoot was affect by high dilution 22mM shoot fresh weight, while the fresh weight root not affect by concentration on bean.

Keywords: *Phaseolus vulgaris* L. (kidney bean), Nutrient solution, shoot, root, hairs.

1.1. Introduction:

Common bean is a staple food in a great number of developing countries, where it is used daily as a primary source of proteins. The average yield of bean varieties cropped in developing countries is still very low. The variables limiting yield include diverse cultivation systems, restricted improved cultivar adoption and susceptibility to biotic and abiotic stresses. Common bean is an important component of the production systems and a major source of protein. Common bean (*Phaseolus vulgaris* L), also referred to as dry bean, is an annual leguminous plant that belongs to the genus, *Phaseolus*, with pinnately compound trifoliolate large leaves. It is largely a self-pollinated plant though cross-pollination is possible if the stigma contacts with pollen coated bee when extended. Seeds are non-endospermic and vary greatly in size and colour from the small black wild type to the large white, brown, red, black or mottled seeds of cultivars, which are 7-16 mm long. Generally, common bean is considered a short-season crop with most varieties maturing in a range of 65 to 110 days from emergence to physiological maturing (Buruchara, 2007). Maturity period can continue up to 200 days after planting (Gomez, 2004). The crop is not sensitive to soil type as long as it is reasonably fertile, well-drained and does not have conditions that interfere with germination and emergence (Wortmann et al., 1998). Common bean contains high protein content, is a good source of energy and provides folic acid, dietary fibre and complex carbohydrates (Edje et al., 1980). Common bean protein is high in lysine, which is relatively deficient in maize, cassava and rice, making it a good complement to these staples in the diet. It is the main grain legume crop. (Pachico, 1993). For the poor, common bean plays a strategic role in alleviating malnutrition but other health related functions exist. Regular consumption of common bean and other pulses is now promoted by health organizations because it reduces the risk of diseases such as cancer, diabetes or coronary



heart diseases in (Leterme and Munoz, 2002). This is because common bean is low in fat and is cholesterol free. It is also an appetite suppressant because it digests slowly and causes a low sustained increase in blood sugar. Researchers have found that common bean can delay the reappearance of hunger for several hours, enhancing weight-loss programs. Common bean is used almost entirely for human consumption but beans require processing before they are eaten to degrade the toxic compound, lectin phyto-haemagglutinin, which would otherwise cause severe gastric upset (Ferris and Kaganzi, 2008). common bean is important for staggering food supply: leaves, pods, green grains and dry beans. It is consumed as boiled green leaves, green immature pods and/or dry grains. The fresh form of grain is the most preferred because of its fresh flavour, good taste, and requires considerably little time to cook (approximately 40 min).

Plants can respond to the environment by altering their development. For example, the root system is highly responsive to nutrient availability and distribution within the soil. This is particularly true of phosphate and nitrate availability, which are the major growth-limiting nutrients in natural environments. Relative to shoot growth, root growth is generally favoured in nutrient-poor soils (Reynolds and D'Antonio, 1996). However, effective nutrient acquisition is not only dependent on the amount of root but also on the three-dimensional deployment of roots, the root system architecture (RSA). There is a large body of evidence demonstrating that RSA can be greatly influenced by nutrient availability, the nutrient status of the plant (Fitter and Stickland, 1992; Williamson et al., 2001; Zhang and Forde, 1998), and the heterogeneity of nutrient supply (Drew, 1975; Zhang and Forde, 1998). However, the mechanisms mediating these changes and their ecological significance are still poorly understood. Shoot nitrate and phosphate status has been shown to play a role in the regulation of the root \pm shoot allocation of resources and the control of RSA. Scheible et al. (1997) found a highly significant inverse correlation between shoot nitrate levels and total root growth. In *Arabidopsis thaliana*, lateral root elongation was suppressed by growth on uniformly high nitrate concentrations (Zhang and Forde, 1998), even though other RSA parameters such as primary root growth and lateral root number remained the same under a wide range of nitrate concentrations (Zhang and Forde, 1998). In many plant species nutrient-rich regions or patches stimulate local lateral root proliferation (Farley and Fitter, 1999). This proliferation response was found to be nutrient-specific in the classical work with barley (*Hordeum vulgare*) (Drew, 1975; Drew and Saker, 1975, 1978; Drew et al., 1973). Drew and co-workers demonstrated that locally applied nitrate, ammonium, and phosphate, but not potassium, stimulated lateral root proliferation within a nutrient-rich zone and suppressed it elsewhere. Localised root proliferation was suggested to be a direct or indirect consequence of changes in metabolic activity in that particular part of the root system. Given the contrasting mobility of nitrate and phosphate ions in soil, one might expect nitrate and phosphate limitations to affect RSA differently. Nitrate diffusion is three to four orders of magnitude faster than that of phosphate (Tinker and Nye, 2000) and the high mobility of nitrate means that roots 1 cm apart might compete for nitrate after only 1 day (Tinker and Nye, 2000). Therefore, a low root density is in theory sufficient to capture all the nitrate in a large volume of soil, raising the question as to why proliferation occurs (Robinson, 1996). However, when two plants grow close together the ability to proliferate roots in nitrogen-rich patches confers a competitive advantage because nitrate uptake is proportional to relative root length density, the root length in a given volume of soil (Hodge et al., 1999; Robinson et al., 1999). In contrast, because of the immobility of phosphate ions, spatial exploitation of soil is particularly important for phosphate acquisition by plant roots.

• 2. Material and Methods:

We use bean plant seeds, sandy soils, nutrient solution (1.375 and 22 mM) and distilled water (DW) as control, pots, filter paper. First: This work aimed to study the effect of some (nutrient solution) treatments (0.0, 1.375, and 22mM) on growth of bean. Pot experiments were carried out during one month, in a growth chamber to investigate the effect of different levels of (nutrient) on growth of bean (*Phaseolus vulgaris* L.). Seeds of bean (*Phaseolus*



vulgaris L. were sown in basins in the chamber growth . At the ten leaf stage, the seedlings were transplanted in pots, 20 cm in diameter. Each pot was filled with of dry sandy soil . Each pot contained one seedling. Wash the soil used in the study with tap water and when washed with distilled water , The seeds were surface sterilized (disinfected) with sodium hypochlorite (Na₂HCl) solution for 3 min and then thoroughly washed for 5 min with distilled water. The soil is placed in large basin and then the seeds are sown them. (Numbering of seeds 90) in the germination chamber . The culture conditions were 16-h light at 25°C and 8-h darkness at 21°C. The pH of nutrient solutions was maintained between 5.4 and 5.6 across all treatments.

It is watered by(DW) every day for ten days. The application of nutrient dilution treatments started when the plants were established (after 10 days from transplanting and transferring to the growth chamber). Plants were watered daily with distal water approximately 1000ml of period 10 days. and then 1000ml of nutrient solution.

Then the seedling are separated in to small potting containing a filter paper and soil and placed in them. Pots are placed in the large basins , each basin contains of 30 pots. It is irrigated by (DW) for a week about 1000ml , after week it is irrigated once with the (nutrient solutions (approximately 1 L/plant) containing (Ca (NO₃)₂ , KNO₃ , Mg (NO₃)₂ , Mg SO₄ , KH₂PO₄). Composition of the nutrient solutions with 1.375 mM was as 0.468 Ca (NO₃)₂ ,0.156 KNO₃ ,0.141 Mg (NO₃)₂ , 1.0 Mg SO₄ , 1.84 KH₂PO₄ , PH 4.5. The nutrient solutions with 22 mM contained was as 0.75 Ca (NO₃)₂ , 0.25 K NO₃ , 0.225 Mg (NO₃)₂ , 0.1Mg SO₄ , 0.184 KH₂PO₄ , PH 4.55. it is estimated at 1000ml. And then irrigated with (DW)again. The following plant growth parameters were measured: Plant height, Number of leaves, leaf length , width of leaf ,this parameters measured were carried by the methods of Akonye and Nwauzoma (2003), root length , fresh and dry weight (shoot and root) (g), number of hairs on upper and lower leaf surface, Specific root length (SRL), and other parameters, per plant.

Developmental stage of the common bean plant for four week:

Stage 1:germination : The nutrient solutions absorption by the seed, emergence of the radicle and transformation , to the primary root.

Stage 2: emergence : cotyledons appear at soil level and begin to separate ,the epicotyl initiates its development.

Stage 3:primary leaves: totally opened primary leaves.

Stage 4: first trifoliolate leaf: the first trifoliolate leaf opens and second appears.

Stage 5:third trifoliolate leaf : the third trifoliolate leaf opens and the buds on the lower nodes produce branches.

Each stage begins of the plants, of the correspond of the description (Van Schoonhoven and Pastor Corrales 1987)

Specific root length (SRL) = Root length / Dry weight root

Numbers of emerged seedlings were recorded daily according to the seedling evaluation handbook of the Association of Official Seed Analysis (AOSA) (1983). (According to Chapman and Pratt (1961).

Root / shoot ratio (R / S) was calculated for each treatment used for corn & wheat as following:
 $R / S = \text{Dry weight of root (g)} / \text{Dry weight of shoot (g)}$.

Hair density=number of hairs / leaf area (cm²)

All data were subjected to statistical analysis according to the method of analysis of variance and value of least significant difference (L.S.D.) at 5% was calculated to compare every two means (Sendicor and cochran, 1980).

At the end of the growing seasons the individual leaf length was measured with a plastic ruler.
Specific shoot length= shoot length / Dry weight shoot

The fresh weights of stems and roots were weighed at end of growing season.

four week-old seedlings were harvested. Plants were divided into root and shoot and oven-dried at 80°C for 48 h for determination of root, stem dry masses.



Relative growth (cm/cm):

This term describes growth measured relative to the initial parameters (West et al 1920)

$$RG = \frac{H_f - H_i}{H_i}$$

Where: H_i = initial height of the plant

H_f = final height of the plant.

1.3. RESULTS AND DISCUSSION :

Growth of *Phaseolus vulgaris* L. seedling under different nutrient solutions (0.0, 1.375 mM, 22 mM) was measured of following :

Various growth parameter such as shoot length and root length in the table 3.1 and Figure 3.1 were not significant differences in the weeks (one , and final for shoot) and not effect on the root length by concentration of nutrient regime.

Table 3.1. Effect of nutrient regime on shoot length (cm) during the first and final weeks and root length (cm) of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant.

± =

SE Mean.

| Treatment (mM) | Shoot length(cm) first week | Shoot length(cm) final week | Root length (cm) |
|----------------|-----------------------------|-----------------------------|------------------|
| 0.00 | + 18.980±0.963 | + 39.35±1.88 | + 24.97±0.94 |
| 1.375 | 20.51±1.09 | 44.97±2.16 | 26.88±2.02 |
| 22.00 | 21.307±0.983 | 43.02±2.36 | 25.30±1.08 |

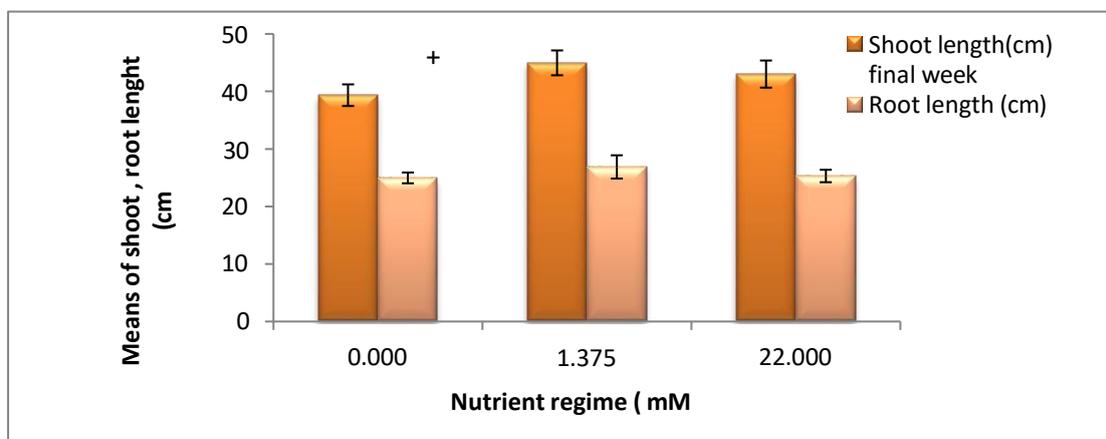


Figure 3.1. Effect of nutrient regime on shoot length (cm) during the final weeks and root length (cm) of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant.

± =

SE Mean.

The parameters of mean of number leaves ,the number leaf pairs(primary leaf) , leaf palmate(first foliolate) and leaf pairs palmate (third trifoliolate)of bean under different nutrient solutions (0.0, 1.375 ,22 mM) were not significant differences in the one week ,whereas the parameters of number leaves ,final week, the number leaf pairs(primary leaf) , leaf palmate(first foliolate) of *Phaseolus vulgaris* L were not significant respectively .(Table 3.2 and Figure 3.2)Whereas leaf pairs palmate (third trifoliolate) ,the results showed significant differences in table 3.2 and figure 3.3. Tukey's pairwise comparisons test reveals significant differences in leaf pairs palmate (third trifoliolate) ($P < 0.032, F = 3.57$) between distal water (control) and concentration



1.375, 22 mM of nutrient regime of the same plant species were promoted under higher concentrations (22mM) of nutrient regime.

Table 3.2. Effect of nutrient regime on number leaves during the first and final weeks of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. * = significant at $P < 0.05$ ± = SEMean.

Similar letters = not significant. Different letters = significant.

| Treatment (mM) | Mean of number leaves | | | | | |
|----------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | Number leaves ,first week | | | Number leaves ,final week | | |
| | + Primary leaf | + First trifoliolate leaf | + Third trifoliolate leaf | + Primary leaf | + First trifoliolate leaf | * Third trifoliolate leaf |
| 0.00 | 1.0±0.00 | 0.88±0.063 | 0.30±0.187 | 1.00±0.0 | 0.50±0.09 | 1.50 ^a ±0.09 |
| 1.375 | 1.03±0.03 | 0.77±0.079 | 0.20±0.074 | 1.00±0.0 | 0.50±0.09 | 1.47 ^b ±0.09 |
| 22.00 | 1.00±0.00 | 0.40±0.051 | 0.30±0.085 | 1.00±0.0 | 0.77±0.08 | 1.20 ^{ab} ±0.07 |

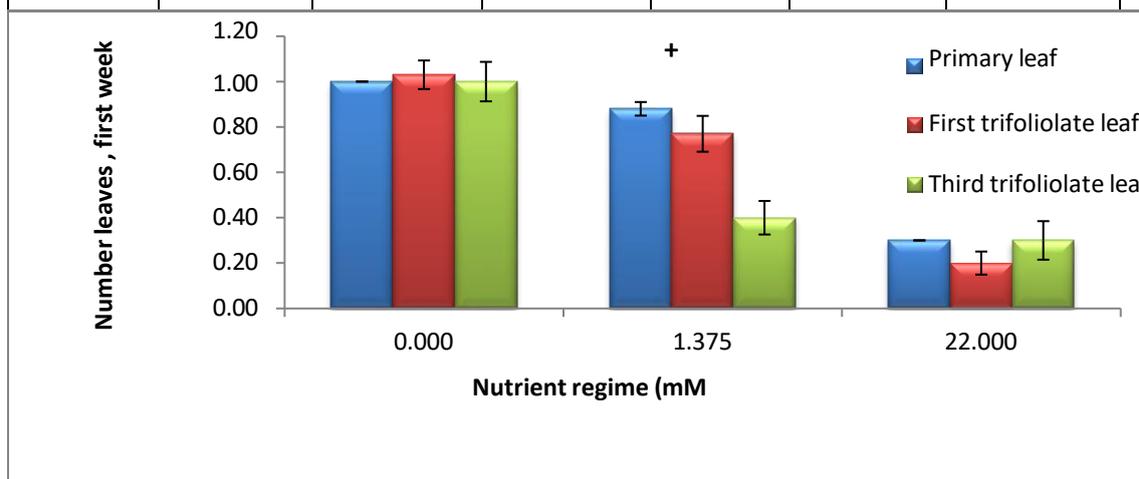


Figure 3.2. Effect of nutrient regime on number leaves during the first weeks of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. ± = SEMean.

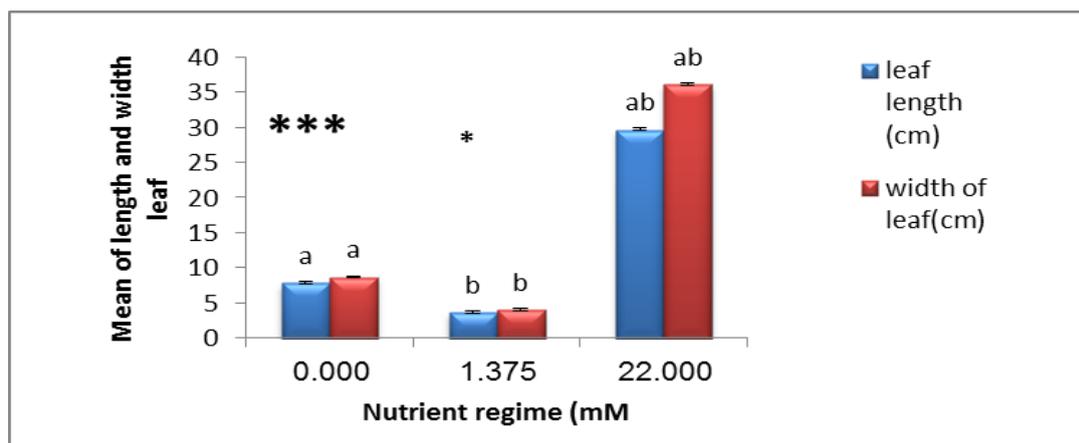


Figure 3.4. Effect of nutrient regime on leaf length (cm) , width of leaf (cm) on final week of *Phaseolus vulgaris* L. (kidney bean).

* = significant at $P < 0.05$.

*** = significant at $P < 0.001$.

Similar letters = not significant. SEMean.

Different letters = significant.

± =

In table 3.4,3.5 and 3.6 ,the parameters of number hairs on adaxial and abaxial leaf surfaces and density of hairs on adaxial and abaxial leaf surface in figure 3.5 and Specific shoot length and Specific root length and Relative growth of *Phaseolus vulgaris* L were not significantly affected by different dilutions of nutrient regime respectively 0.0,1.375,22mM.

Table 3.4. Effect of nutrient regime on the mean number of hairs on adaxial and abaxial leaf surfaces of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. Mean.

± = SE

| Treatment (mM) | Mean hair number | |
|----------------|------------------|-----------------|
| | adaxial | abaxial |
| 0.00 | + 115.3±5.32 | + 230.1±11.2 |
| 1.375 | 116.8±4.60 | 230.8±8.41 |
| 22.00 | 112.1±5.55 | 216.3±10.7 |

Table 3.5. Effect of nutrient regime on density of hairs on adaxial and abaxial leaf surfaces of *Phaseolus vulgaris* L. (kidney bean)

+ = Not significant. Mean.

± = SE

| Treatment (mM) | Mean density | |
|----------------|----------------------|----------------------|
| | adaxial leaf surface | abaxial leaf surface |
| 0.00 | + 3.91 ± 0.23 | + 7.78 ± 0.54 |
| 1.375 | 3.46 ± 0.23 | 6.82 ± 0.42 |
| 22.00 | 3.82 ± 0.31 | 7.43 ± 0.62 |



Table 3.6. Effect of nutrient regime on Specific shoot and root length and Relative growth (cm/cm) of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. ± = SE
Mean.

| Treatment (mM) | Specific shoot length | Specific root length | Relative growth |
|----------------|-----------------------|----------------------|-----------------|
| 0.00 | + 117.8±5.05 | + 207.9±16.6 | + 1.098±0.06 |
| 1.375 | 123.8±11.9 | 193.1±14.1 | 1.248±0.08 |
| 22.00 | 142.1±25.5 | 200.9±16.8 | 1.040±0.08 |

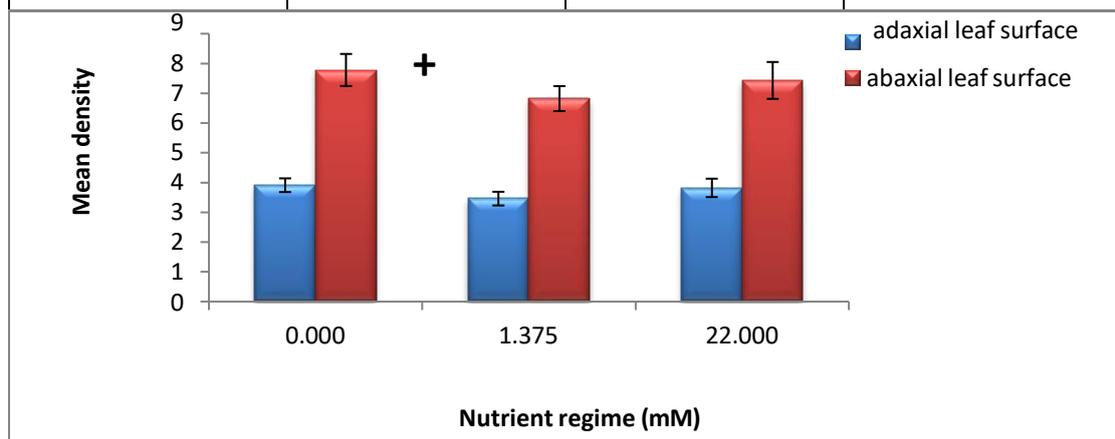


Figure 3.5. Effect of nutrient regime on density of hairs on adaxial and abaxial leaf surfaces of *Phaseolus vulgaris* L. (kidney bean)

+ = Not significant. ± = SE
Mean.

The measures of parameters of seedling kidney bean, of the shoot fresh weight was affect by different concentration of nutrient regime 1.375 ,22mM, included the control ,show in table 3.7. Tukey's pariwise comparisons test reveals significant differences ($P < 0.001, F = 7.87$) in shoot fresh weight within control and dilution 1.375,22mM, but parameters of root fresh weight ,shoot and root dry weight and Root/shoot ratio root were not significant show table 3.7 and figure 3.6,3.7.

Table 3.7. Effect of nutrient regime on fresh and dry weight (g) of shoots, roots and root /shoot ratio of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. *** = significant at $P < 0.001$ ± = SEMean.

Similar letters = not significant. Different letters = significant.

| Treatment (mM) | Mean values | | | | |
|----------------|--------------------------------|----------------------|----------------------|---------------------|------------------|
| | Shoot fresh weight (g) | Root fresh weight(g) | Shoot dry weight (g) | Root dry weight (g) | Root/shoot ratio |
| 0.00 | *** 2.45 ^a ±0.20 | + 1.29±0.097 | + 0.352±0.023 | + 0.134±0.008 | + 0.40±0.025 |

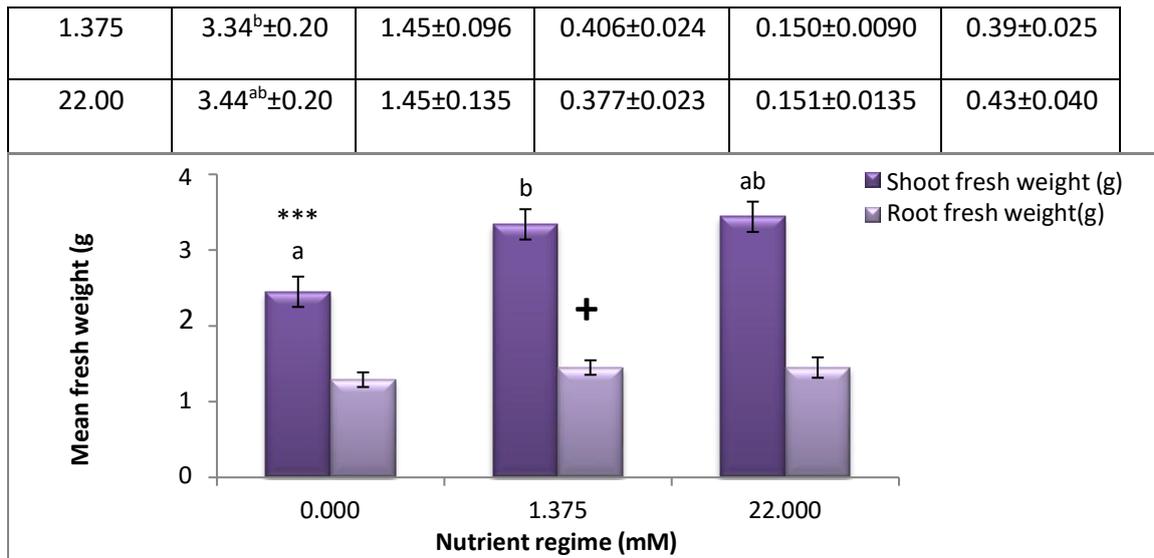


Figure 3.6. Effect of nutrient regime on shoot and root fresh weight (g) of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. *** = significant at $P < 0.001$ ± = SEMean.

Similar letters = not significant. Different letters = significant.

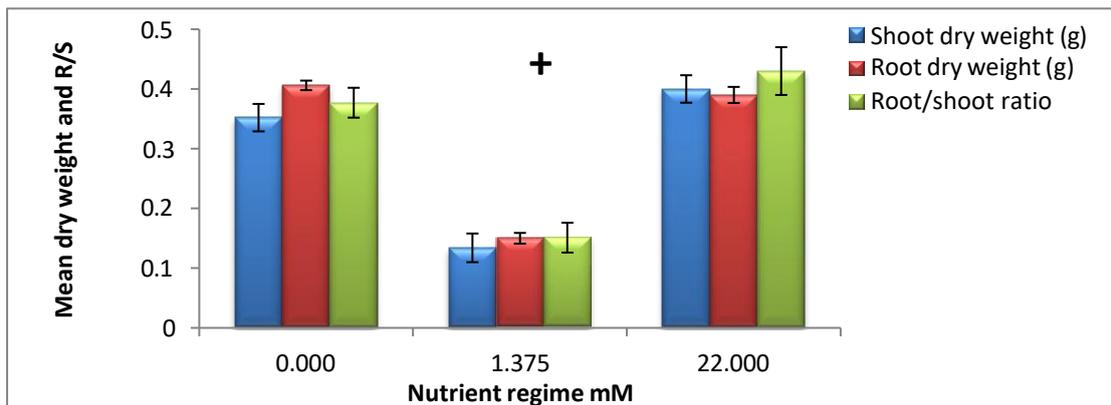


Figure 3.7 Effect of nutrient regime on shoot and root dry weight (g) of and root /shoot ratio of *Phaseolus vulgaris* L. (kidney bean).

+ = Not significant. ± = SE

The spatial – temporal fluctuation and occurrences of nutrient in the soil are monitored by sensory mechanisms at root tips. This information triggers chemical signals which may stop root growth (Asim et al 2020). The decrease in root length and root bio mass up on N and P deficiency. In most studies, deficiency of nutrient, (e.g. phosphorus) supply, decreased absolute root biomass (dry weight) as found in maize (Sheng et al 2012), Zhang et al 2012 – Deng et al 2014, Li et al 2017) oilseed rape (Duan et al 2020) sugar beet (Hadir et al 2021) wheat (Teng et al 2013) and common bean (Ochoa et al 2006). yet many studies have also demonstrated that high ammonium concentrations inhibit conifer fine root production (Van Dijk et al., 1990; Boxman et al., 1991; Olsthoorn et al., 1991; Ohlund and Nasholm 2001). Most conifer species exhibit far greater specific uptake rates for NH_4^+ compared to NO_3^- , (e.g. Rygiewicz et al., 1984a,b; Kamminga-van Wijk and Prins, 1993; Buchmann et al., 1995; Kronzucker et al., 1997). NO_3^- had relatively small effects on N nutrition, increasing the proportion in the growing medium strongly depressed uptake of P, K, Ca and Mg. In general,



the maintenance of charge balance across the plasmalemma is one of the key mechanisms by which NO₃ is thought to influence the uptake of other nutrient elements. (Mengel and Kirkby, 2001). Effect the compounds (containing (Ca (NO₃)₂ , KNO₃ , Mg (NO₃)₂ , Mg SO₄ , KH₂PO₄). on measures of bean showed on the results .

References

- Reynolds, H.L. and D'Antonio, C. (1996) The ecological significance of plasticity in root weight ratio in response to nitrogen. *Plant Soil*, 185,75±97.
- Robinson, D. (1996) Variation, co-ordination and compensation in root systems in relation to soil variability. *Plant Soil* 187, 57±66.
- Robinson, D., Hodge, A., Griffith, B.S. and Fitter, A.H. (1999) Root proliferation in nitrogen-rich patches confers competitive advantage. *P. Roy. Soc. Lond. B-Bio.* 266, 431±435.
- Tinker, P.B. and Nye, P.H. (2000) *Solute Movement in the Rhizosphere*. Oxford: Oxford University Press.
- Williamson, L.C., Ribrioux, S.P.C.P., Fitter, A.H. and Leyser, H.M.O. (2001) Phosphate availability regulates root system architecture in *Arabidopsis*. *Plant Physiol.* 126, 875±890.
- Zhang, H. and Forde, B.G. (1998) An *Arabidopsis* MADS box gene that controls nutrient-induced changes in root architecture. *Science* 279, 407±409.
- Fitter, A.H. and Stickland, T.R. (1992) Architectural analysis of plant root systems III. Studies on plants under field conditions. *New Phytol.* 121, 243±248.
- Farley, R.A. and Fitter, A.H. (1999) The responses of seven cooccurring woodland herbaceous perennials to localized nutrient-rich patches. *J. Ecol.* 97, 849±859.
- Drew, M.C. (1975) Comparison of the effects of a localised supply of phosphate, nitrate, ammonium and potassium on the growth of the seminal root system, and the shoot, in barley. *New Phytol.* 75, 479±490.
- Drew, M.C. and Saker, L.R. (1975) Nutrient supply and the growth of the seminal root system in barley. II. Localised, compensatory increases in lateral root growth and rates of nitrate uptake when nitrate supply is restricted to only part of the root system. *J. Exp. Bot.* 26, 79±90.
- Drew, M.C. and Saker, L.R. (1978) Nutrient supply and the growth of the seminal root system in barley. III. Compensatory increases in growth of lateral roots, and in rates of phosphate uptake in response to a localised supply of phosphate. *J. Exp. Bot.* 29, 435±451.
- Drew, M.C., Saker, L.R. and Ashley, T.W. (1973) Nutrient supply and the growth of the seminal root system in Barley. *J. Exp. Bot.* 24, 1189±1202.
- Hodge, A., Robinson, D., Griffiths, B.S. and Fitter, A.H. (1999) Why plants bother: root proliferation results in increased nitrogen capture from an organic patch when two grasses compete. *Plant Cell Environ.* 22, 811±820.
- Scheible, W.-R., Laurerer, M., Schulze, E.-D., Caboche, M. and Stitt, M. (1997) Accumulation of nitrate in the shoot acts as signal to regulate shoot-root allocation in tobacco. *Plant J.* 11, 671±691.



- Snedecor, G.W. and Cochran, W.G.(1980). “Statistical methods” 7th Edition, The Iowa State University Press, Ames, Iowa, USA.
- Chapman, H.D. and Pratt, P.F. (1961). Methods *of* analysis for **soil**, plant and water. Univ. of California, Davis. Cobley, L.S. and W.M. Steele (1976). An introduction to the botany of tropical crops, Longman group Limited, London
- Buruchara, R. (2007). Background information on Common Beans (*Phaseolus vulgaris* L) in Biotechnology, Breeding & Seed Systems for AfricanCrops. <http://www.africancrops.net/rockefeller/crops/beans/index.htm>.
- Gomez, O. (2004). Evaluation of Nicaraguan common bean(*Phaseolus vulgaris* L.) landraces. Doctoral thesis, Department of ecology and crop production sciences Uppsala, Swedish University of Agricultural Sciences
- Wortmann, C.S, R. A. Kirby, C.A. Eledu and D.J.Allen (1998). Atlas of common bean production in Africa, CIAT publication No. 297.
- Edje, O.T., L.K. Mughogho, Y.P. Rao and W.A.B Msuku (1980). Bean production in Malawi. In Potential for field beans in Eastern Africa. Proceedings of a Regional Workshop held in Lilongwe, Malawi 9-14 march 1980.
- Pachico, D. (1993). The demand for bean technology. In Rachier,G.O. ;
- P.M.Kimani., R, Juma and L. Ongadi. bean research activities at KARI Kakamega. (UnPublished report)
- Leterme, P. and C. Munoz (2002). Factors influencing pulse consumption in Latin America. British journal of Nutrition 88.Suppl.3,s251-s254.
- Ferris, S. and E. Kaganzi (2008). Evaluating marketing opportunities for haricot beans in Ethiopia. Rural agro-enterprise development project report
- West ,C.,G.C. Brigg and F.Kidd,1920.Methods and significant relations in quantitative analysis of plant growth . New Phytol., 19:200-207
- Van Schoonhoven ,A. and Pastor – Carrales,M.A. (1987) Standard system for the evaluation of bean germplasm. Centro International Agricultura Tropical (CIAT).Cali,Colombia.
- Akonye and Nwauzoma (2003) Growth measurement in plant. In Research techniques in biological and chemical sciences, Onyeike,E.N and Osuji,J.O (Eds),1 st Edn, Spring Field Publishers, Owerri,pp:147-154.
- Asim,M.,Ullah,Z.,XU, F., An, L., Aluko,O.O.,Wang, Q., etal (2020).Nitrate signaling , functions,and regulation of root system architecture :Insight from Arabidopsis thaliana . Genes (basel)11,E633.doi: 10.3390/genes11060633.
- Van Dijk, H.F.G., Louw, M.H.J., Roelofs, J.G.M., Verburgh, J.J., 1990. Impact of artificial ammonium-enriched rainwater on soils and young coniferous trees in a greenhouse. Part II Effects on the trees. Environ. Pollut. 63, 41–59.
- Boxman, A.W., Krabbendam, H., Bellemakers, M.J.S., Roelofs, G.M., 1991. Effects of ammonium and aluminum on the development and nutrition of *Pinus nigra* in hydroculture. Environ. Pollut. 73, 119–136.
- Olsthoorn, A.F.M., Keltjens,W.G., Van Baren, B., Hopman, M.C.G.,



- 1991. Influence of ammonium on fine root development and rhizosphere pH of Douglas-fir seedlings in sand. *Plant Soil* 133, 75–81.
- Ohlund, J., Nasholm, T., 2001. Growth of conifer seedlings on organic and inorganic nitrogen sources. *Tree Physiol.* 21, 1319– 1326.
- Rygiewicz, P.T., Bledsoe, C.S., Zasoski, R.J., 1984a. Effects of ectomycorrhizae and solution pH on [N-15]ammonium uptake by coniferous seedlings. *Can. J. For. Res.* 14, 885–892.
- Rygiewicz, P.T., Bledsoe, C.S., Zasoski, R.J., 1984b. Effects of ectomycorrhizae and solution pH on [N-15]nitrate uptake by coniferous seedlings. *Can. J. For. Res.* 14, 893–899.
- Kamminga-vanWijk, C., Prins, H.B.A., 1993. The kinetics of NH₄⁺ and NO₃⁻ uptake by Douglas fir from single N solutions and solutions containing both NH₄⁺ and NO₃⁻. *Plant Soil* 151, 91–96.
- Buchmann, N., Schulze, E.D., Gebhauer, G., 1995. 15N-ammonium and 15N-nitrate uptake of a 15-year-old *Picea abies* plantation. *Oecologia* 102, 361–370.
- Kronzucker, H.J., Siddiqi, M.Y., Glass, A.D.M., 1997. Conifer root discrimination against soil nitrate and the ecology of forest succession. *Nature* 385, 59–61.
- Mengel, K., Kirkby, E.A., 2001. *Principles of Plant Nutrition*, fifth ed. Kluwer Academic Publishers, Dordrecht, Boston.
- Li.H., Mollier.A. Ziabi.N.,Shi.Y., Parent.L-E.,Morel.C.(2017).The long- term effects of tillage practice and phosphorus fertilization on the distribution and morphology of corn root , *plant soil* 412-97-114.doi:10.1007/511104-016-2925-y.
- Teng.W.,Deng.Y., Chen.,X-P.,Xu.,X.F Chen .R.-Y.LV,Y., etal (2013). Characterization of root response to phosphorus supply from morphology to gene analysis in field –grown wheat . *J.Exp.Bot.*64,1403-1411.doi:10.1093/jxb/ert.023.
- Deng.Y.Chen.K.Teng.W. Zhan.A,Tong.y.,Feng.G., etal (2014) is the inherent potential of maize roots efficient for soil phosphorus acquisition? *Plos One* 9.e 90287.doi:101371/Journal .pone. 0090287.
- AOSA. (1983). *Seed vigor testing handbook*. Contribution 32, Handbook on Seed Testing, AOSA, Lincoln, NE, USA.
- Duan, X., Jin,K., Ding ,G., Wang,C., Cai,H., Wang,S., etal (2020) the impact of different morphological and biochemical root traits on phosphorus acquisition and seed yield of brassica napus. *Field Crops Res.* 258,107960. Doi: 10.1016/j.fcr.2020.107960
- Hadir,S., Gaiser,T., Hugging, H., Athmann, M., Pfarr,D., Kemper, R., etal .(2021).Sugar beet shoot and root phenotypic plasticity to nitrogen, phosphorus ,potassium and lime omission .*Agriculture* 11,21. doi:10.3309/ agriculture 11010021
- Ochoa, I.E., Blair, M. W., Lynch ,J.P. (2006).QTL analysis of adventitious root formation in common bean under contrasting phosphorus availability. *Crop Sci.* 46,1609-1621.doi:10.2135/cropsci2005.12-0446
- Sheng, M., Lalande, R.,Hamel, C., Ziadi , N., Shi,Y.(2012).Growth of corn roots and associated arbuscular mycorrhizae are affected by long-term tillage and phosphorus fertilization. *Agron.J.*104,1672-1678.doi: 10.2134/ agronj 2012.0153



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- Zhang , Y., YU, P., Peng ,Y.-F., L, X.-X., Chen, F.-J., LI, C.J. (2012)Fine root patterning and balanced inorganic phosphorus distribution in the soil indicate distinctive adaptation of maize plants to phosphorus deficiency . *Pedosphere* 22,870-877.doi:10.1016/S1002-0160(12)60073-3