# Effects of soil moisture, potassium and nitrogen on mineral absorption and growth of **Coffea arabica** L.[*1/]

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## COMPENDIO

*Se estudió la obsorción de NPK por plántulas de café en macetas con diferentes humedades de suelo en relación con los niveles de aplicación de estos minerales. La absorción de N y K no fue afectada hasta el 50 por ciento de la capacidad de campo pero fue retardada por un régimen más bajo de humedad del suelo. La absorción de fósforo no fue menor ni aun a la más baja humedad de suelo probada en la presente investigación. El nitrógeno y el potasio mostraron una interacción positiva mientras que se observó una interacción negativa entre N y P. La absorción estuvo bien relacionada con la cantidad de mineral aplicada.*

*El nitrógeno aumentó el crecimiento en extensión, área foliar así como también el número de nudos. El potasio produjo efectos similares en los dos primeros pero no en el número de nudos. Se notó crecimiento compensatorio después de que las plantas, mantenidas originalmente a una baja humedad de suelo, fueron ampliamente regadas. El nitrógeno actuó aditivamente al exhibir crecimiento compensatorio. Se mencionan las implicaciones prácticas de este trabajo.*


## *Introduction*

APPLICATION of nitrogenic fertilizers to increase yield is a common practice throughout the world. Yield quite often does not reflect very well the amount of fertilizer applied to the soil, and on many occasions either there have been no increases in yield or insignificant increases only. This can result due to various causes but the efficiency of absorption of applied fertilizers can be an important one. There is no doubt that absorption is a complicated process, which depends upon various other factors other than just the amount.

Soil moisture is a major factor influencing the absorption of different minerals (22) and growth of plants (9, 13). For example, it is reported that N is absorbed slightly more at a moisture level a little lower than the field capacity (22). For K, the picture is not clear. Some authors have reported higher rate of absorption of K (23, 30), others have observed lower rates of absorption as the moisture level is lowered below the field capacity (28, 30). For P similarly different views have been expressed.

The level of one mineral on its own absorption (17) and on the absorption of other minerals have always been the subject of study (19). On many occasions one mineral is found to antagonize the absorption of the other (1, 6, 27). There are also cases where one mineral is found to enhance tha rate of absorption of the other (5, 7, 12, 15, 18, 19, 21, 24).

Absorption of minerals in relation to different levels of soil moisture and minerals must reflect in the growth of the plant. Moisture level by itself is a modifying factor of growth (10, 26). Absorption is a feature which is apparently specific to a particular plant species (2) and it is possible that information in this respect from other plants may not be applicable to coffee and therefore, this aspect needs to be investigated.

In the present work the absorption of nitrogen, potassium and phosphorus was studied in coffe seedlings at differents levels of moisture, potassium and

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nitrogen supplied to the pot soil. Growth measurements, in terms of extension growth, increase in node number and areas of individual leaves, were also carried out

## *Materials and Methods*

Plants were raised from seeds of *Coffea arabica* L. cv 'K7' and planted in black polythene bags 27 × 10 cm lay flat The poting medium contained a mixture of soil, farmyard manure and polystyrene granules. When the seedlings were about one year old, they were then transferred to 18 cm pots. Each pot contained approximately 1.5 kg (dry wt) of Kikuyu red loam soil The soil used in these pots was collected from a locality which was poor in most of the essential mineral elements. On the basis of soil analysis, essential elements were supplemented to the pot soil. They were further treated to have two levels of N, three levels of K and three levels of moisture as given below:

Potassium levels:

| Low | Medium | High |
|---|---|---|
| No additional K | 2.75 KCL/pot | 7.25g KCL/pot |

Nitrogen levels:

| Low N | High N |
|---|---|
| No additional N | 10.25 g $Ca(NO_3)_2$/pot |

Moisture regimes:

| High | Medium | Low |
|---|---|---|
| 95 ± 5% | 55 ± 5% | 40 ± 5% of field capacity |

Absorption rates were studied by carrying out soil and leaf analyses at intervals using Atomic Absorption and Auto-analyzer Mineral losses, giving an estimate of rate of depletion and thus of absorption from the pot soil, were calculated by subtracting the final amount of a mineral from the initial after a period of time Absorption rates given here only represent a comparative account for various elements studied.

## *Results*

Potassium and phosphorus losses from the soil, between the 1st and the 4th month of treatment, are given in Table 1 and Table 2 respectively. In order to lower the number of samples for analysis, soil samples were taken from pots with the same treatment and combined together before analysis and therefore, the data could not be subjected to statistical analysis. From Table 1, it is apparent that when soil water was low loss of K was significantly reduced. However, it was not affected at the intermediate moisture regime. At high levels of soil K, there was more depletion from the soil indicating higher rate of absorption. When soil N was high, potassium was taken in by the plants in greater amount (Table 1).

Table 1.—Potassium losses from the soil, between the 1st and the 4th month of treatments, in relation to the levels of soil water, nitrogen and potassium, (amounts are in m.e. per cent).

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 0.00 | 0.81 | 0.45 | 0.42 |
| | High | 0.00 | 0.46 | 0.96 | 0.47 |
| | Mean | 0.00 | 0.64 | 0.71 | 0.45 |
| Medium | Low | 0.02 | 0.61 | 0.51 | 0.38 |
| | High | 0.01 | 0.58 | 1.07 | 0.55 |
| | Mean | 0.02 | 0.60 | 0.79 | 0.47 |
| Low | Low | 0.02 | 0.13 | 0.50 | 0.32 |
| | High | 0.00 | 0.14 | 0.72 | 0.29 |
| | Mean | 0.01 | 0.14 | 0.61 | 0.25 |

Table 2.—Phosphorus losses from the soil, between the 1st and the 4th month of treatments, in relation to the levels of soil water, nitrogen and potassium (amounts are given in parts per million).

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 7.0 | 13.0 | 5.0 | 8.3 |
| | High | 6.0 | 2.0 | 0.0 | 2.7 |
| | Mean | 6.5 | 7.5 | 2.5 | 5.5 |
| Medium | Low | 6.0 | 10.0 | 9.0 | 8.3 |
| | High | 5.0 | 7.0 | 0.0 | 4.0 |
| | Mean | 5.5 | 8.5 | 4.5 | 6.2 |
| Low | Low | 10.0 | 9.0 | 12.0 | 10.3 |
| | High | 0.0 | 3.0 | 10.0 | 4.3 |
| | Mean | 5.0 | 6.0 | 11.0 | 7.3 |

Phosphorus depletion from the soil did not seem to follow the trend of K (Table 2). There was a gradual increase in P loss with decreasing soil moisture. Leaf P concentrations were also roughly affected in the same way in relation to moisture regimes The amount of soil K did not give any consistent picture as to the uptake of P, but it can be seen that when N was deficient, larger amounts of P were lost from the soil than when N in soil was high (Table 2).

From the leaf analysis data (Table 3) it can be seen that increasing the amount of soil nitrogen increased significantly the amount of leaf nitrogen, but there was no significantly effect of water stress on the amount of N in leaves, although at the lowest moisture supply provided, slightly lower level of N was recorded in the leaf There was no significant interaction between nitrogen and potassium

*Extension growth during the period of water stress* A marked primary branch, second or third from the shoot tip, was measured during water stress treatments Mean lengths of the branches after 12 week are given in Table 4, as percentage of the original length Analysis of variance shows that nitrogen and potassium had highly significant effect on growth Water stress significantly reduced extension growth Considerable interaction occurred between nitrogen and water stress and between potassium levels and water, but there was no interaction beween nitrogen and potassium levels Pairwise analysis of the results is presented in Fig 1

Table 4.—Effects of soil N and K and water on extension growth. (% increase in branch length).

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 6 30 | 9 45 | 21 59 | 12 44 |
| | High | 26 55 | 47 05 | 38 68 | 37 43 |
| | Mean | 16 43 | 28 25 | 30 13 | 24 94 |
| Medium | Low | 15 20 | 8 33 | 15 20 | 12 91 |
| | High | 29 58 | 22 98 | 58 43 | 37 00 |
| | Mean | 22 39 | 15 66 | 36 82 | 24 96 |
| Low | Low | 8 23 | 2 73 | 8 68 | 6 55 |
| | High | 10 23 | 7 30 | 12 28 | 10 27 |
| | Mean | 9 23 | 5 02 | 10 98 | 8 41 |

LSD (between any two treatments) ($P<0\ 05$) = 13 54

Table 3.—Effects of soil nitrogen, potassium and water on total leaf nitrogen, as % dry matter (Each number is a mean of 3 replicates).

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 1 93 | 1 97 | 2 26 | 2 05 |
| | High | 3 31 | 3 08 | 3 07 | 3 15 |
| | Mean | 2 62 | 2 53 | 2 67 | 2 60 |
| Medium | Low | 2 03 | 1 96 | 2 03 | 2 01 |
| | High | 3 09 | 3 10 | 3 15 | 3 11 |
| | Mean | 2 56 | 2 53 | 2 59 | 2 55 |
| Low | Low | 2 02 | 2 01 | 2 05 | 2 03 |
| | High | 2 80 | 2 63 | 2 98 | 2 80 |
| | Mean | 2 41 | 2 32 | 2 52 | 2 42 |

LSD (between any two treatments) ($P<0\ 05$) = 0 50

Table 5.—Increase in the number of nodes during water stress. The numbers represent means for 4 replicates.

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 0 50 | 0 25 | 0 50 | 0 42 |
| | High | 1 50 | 1 75 | 1 50 | 1 68 |
| | Mean | 1 00 | 1 00 | 1 00 | 1 00 |
| Medium | Low | 0 25 | 0 25 | 0 25 | 0 25 |
| | High | 1 25 | 1 50 | 1 50 | 1 42 |
| | Mean | 0 75 | 0 88 | 0 88 | 0 84 |
| Low | Low | 0 25 | 0 50 | 0 25 | 0 33 |
| | High | 0 50 | 0 75 | 0 75 | 0 67 |
| | Mean | 0 38 | 0 63 | 0 50 | 0 50 |

LSD (between any two treatments) ($P<0\ 05$ = 0 80

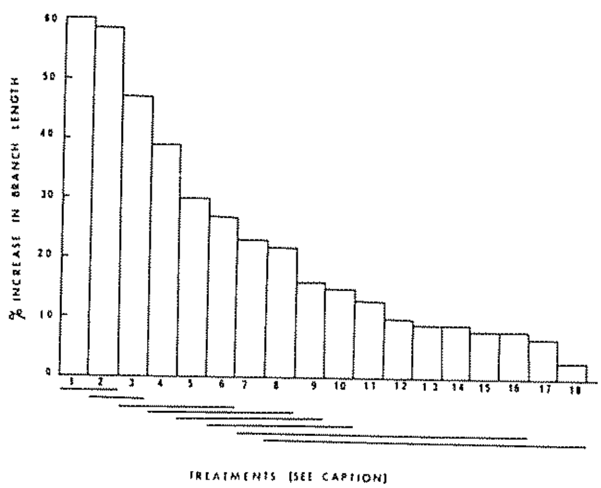


Fig 1.—*The effects of nitrogen potassium and water stress on extension growth. The 18 treatments are arranged in order of decreasing growth values. The horizontal lines connect treatments that are not significantly different.*

1. *Medium $H_2O$-High K-High N*
2. *High $H_2O$-Medium K-High N*
3. *High $H_2O$-High K-High N*
4. *Medium $H_2O$-Low K-High N*
5. *High $H_2O$ -Low K-High N*
6. *Medium $H_2O$- Medium K-High N*
7. *High $H_2O$ - High K- Low N*
8. *Medium $H_2O$ - Low K - Low N*
9. *Medium $H_2O$ - High K - Low N*
10. *Low $H_2O$-High K-High N*
11. *Low $H_2O$-Low K-High N*
12. *High $H_2O$-Medium K- Low N*
13. *Low $H_2O$-High K-Low N*
14. *Medium $H_2O$- Medium K-Low N*
15. *Low $H_2O$ - Low K - Low N*
16. *Low $H_2O$ - Medium K - High N*
17. *High $H_2O$ - Low K - Low N*
18. *Low $H_2O$ - Medium K- Low N*

*Other components of yield—Number of nodes*: The number of nodes was counted at the interval of 2 weeks for 12 weeks Statistical Nitrogen had a higly significant effect on increase in the number of nodes. Water stress significantly reduced the node number. Potassium did not show any significant effect on the number of nodes There was a significant interaction between nitrogen and moisture levels.

*Leaf area*. The youngest fully open leaf on the second or the third primary branch was measured at 2 week intervals. The final area of this leaf after 8 weeks, is shown in Table 6. For each treatment a mean of the leaf pair was found and four replicates were taken. Analysis of the leaf area data showed that nitrogen increased the area of individual leaves significantly ($P = 0.01$) and water stress reduced it significantly Potassium levels had a significant effect ($P = 0.01$) on leaf area, the leaf area increased with increased soil potassium. There was no significant interaction between any two of the treatments.

*Extension growth during recovery from water stress.* Extension growth during this period, was estimated using the same labelled branches as those used in the experiment above. All the pots were then watered to the "high water" level. The increase in length was expressed as percentage of length before rewatering The measurements were taken after five weeks of treatment which are presented in Table 7. Analysis of variance showed that the original level of soil moisture very significantly ($P = 0.05$) affected growth during recovery from water stress in the sense that plants which had been continuously supplied with "high water" grew less than those which were first subjected to water stress and then watered. As was the case for growth during water stress period, nitrogen increased growth during the recovery also Potassium did not make any significant contribution.

## *Discussion*

Fertilization of soil to increase yield is an important aspect of crop management The work described here throws some light in this direction. Yield recordings were not possible because the plants which were used in this work were too young to flower and have fruits However, yield components, as they are called and which are the parameters reflecting yield, were measured

Table 6.—The effects of soil N, K, and water on single leaf area. The numbers are means for four replicates (in $cm^2$).

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| High | Low | 17.84 | 26.37 | 27.47 | 23.89 |
| | High | 42.47 | 36.56 | 48.51 | 42.51 |
| | Mean | 30.16 | 31.47 | 37.99 | 33.21 |
| Medium | Low | 16.66 | 18.24 | 24.36 | 19.75 |
| | High | 32.70 | 42.00 | 45.31 | 40.00 |
| | Mean | 24.68 | 30.12 | 34.84 | 29.88 |
| Low | Low | 12.36 | 14.78 | 18.62 | 15.25 |
| | High | 16.88 | 23.17 | 35.70 | 25.25 |
| | Mean | 14.62 | 18.98 | 27.16 | 20.25 |

LSD (between any two treatments) ($P < 0.05$) = 12.68

Table 7.—The effects of soil N, K and original levels of soil moisture on extension growth during recovery from water stress. The values represent the % increase after the period of withholding water.

| Water | Nitrogen | Potassium | | | |
|---|---|---|---|---|---|
| | | low | medium | high | mean |
| Originally High | Low | 0.00 | 4.70 | 4.67 | 3.12 |
| | High | 2.57 | 1.20 | 0.70 | 1.49 |
| | Mean | 1.29 | 2.95 | 2.69 | 2.31 |
| Originally Medium | Low | 0.27 | 0.53 | 2.03 | 0.94 |
| | High | 5.50 | 9.50 | 2.27 | 5.76 |
| | Mean | 2.89 | 5.02 | 2.15 | 3.35 |
| Originally Low | Low | 17.07 | 8.10 | 6.43 | 10.53 |
| | High | 25.17 | 25.27 | 17.47 | 22.64 |
| | Mean | 21.12 | 16.69 | 11.95 | 16.59 |

LSD (between any two treatments) ($P < 0.05$ = 10.70)

Uptake of K and N was not affected at 50 per cent soil moisture level, but at the lowest level the absorption of these two elements was retarded. There was no effect of soil moisture regime on P absorption. Phosphorus absorption apparently increased slightly as the soil moisture level decreased. Richards and Wadleigh (22) concluded from their work on various major elements that decreasing water supply produced a definite increase in N concentration, a definite decrease in K concentration and a variable effect of P, Ca and Mg concentrations in the plant. Mederski (16) also noted lower percentages of P and K in plants subjected to water stress. Our results here agree for N but disagree for K and P. This may be related to plant specific differences (2, 25).

As far as the interaction among the elements was concerned it was found that in the presence of high soil N more K was taken in by the plant. Similar positive interaction of Ca on K accumulation has been observed previously (7, 11, 12, 15). Potassium has also been found to influence positively the absorption of N (8). In the present work P showed negative interaction with N in the sense that at a lower level of N more P was absorbed. Phosphorus has been found to interact negatively with Zn in some other work (1). A clear picture of P uptake for varying levels of K could not emerge from this study. Concentration effect is quite marked. Thus, increasing levels of soil N and K resulted in greater accumulation of these elements in plants.

Nitrogen increased extension growth, leaf area as well as node number. Potassium influenced only the first two parameters but could not increase the number of nodes. Lack of interaction between the two elements apparently shows that they have a separate site of action and effect through independent means a particular process.

Stress affected all the parameters of growth adversely. Plants originally water stressed and therefore growing least rapidly, grew faster, when later they were amply watered, than those plants that received adequate water supply throughout. Also here plants which were receiving a higher supply of nitrogen grew more than the plants which were originally receiving low nitrogen. This clearly points out that although N was stored during the stress treatment, it could not produce any effect because of the lack of other conditions of growth such as a proper degree of turgidity. Potassium in this respect failed to produce any effect. Nitrogen affects hormone levels, especially of gibberellins (20). Browing (3) found that exogenous application of gibberellins before the rains enhanced the growth when the rains started. It may be assumed therefore that N by increasing the level of gibberellins and storing it in plants until a favourable turgidity level is achieved may have acted in the same way. Potassium has not been reported to affect the level of any hormone. This may be the reason why it failed to produce an effect similar to N.

The work described here casts some light on how different minerals are absorbed and how they affect the growth of coffee. From the present investigation it appears that N and K may be applied to soil together as they have been found to interact positively in their uptake, whereas P should be applied independently because of its negative interaction with N. Moisture level upto 50% of field capacity did not seem to affect absorption of the major elements although it affected some components of growth. Therefore, it is possible that by maintaining a right level of soil moisture growth periodicity, which is an important aspect of cropping regulation, may be achieved. It is also known from the previous work (14) that other synthetic processes such as photosynthesis are not very much affected at this moisture level. This way one can also economize on the crop water use. However, it is important that coffee trees should be sufficiently irrigated when growth is desired.

The recommendation from this work has been made from studies using potted plants only. Therefore, it should be deemed tentative until studies using field trees are completed, althrough Cannell (4) has concluded from his work that for most physiological behaviour coffee seedlings and young trees act alike.

*Summary*

Absorption of NPK by potted coffee seedlings was studied at different soil moistures and in relation to the application levels of these minerals. Various growth components were also measured.

Absorption of N and K was not affected upto 50% field capacity but at the lower soil moisture regime it was retarded. Phosphorus absorption was not lowered even at the lowest soil moisture tested in the present work. Nitrogen and potassium showed a positive interaction whereas a negative interaction was observed between N and P. Absorption was fairly well related to the amount of mineral applied.

Nitrogen increased extension growth, leaf area as well as the node number. Potassium produced similar effects on the first two but not on the node number. Compensatory growth was noted after the plants, originally maintained at low soil moisture, were amply watered. Nitrogen appeared to act additively in exhibiting compensatory growth. Practical implications of this work are mentioned.

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