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ROLE OF POTASSIUM ON GROWTH AND WATER RELATIONS OF RUBBER PLANTS

Lalani Samarappuli, N Yogaratnam P Karunadasa, U Mitrasena
and R Hettiarachchi
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ABSTRACT

Results obtained on the role of potassium (K) and moisture on growth and water relations of *Hevea brasiliensis* are presented in this paper. Assessments of plant diameter and height made at the end of 3,6,9 and 12 months after commencement of the experiment showed that the plant diameter and height with watering at 50% depletion of available water level (M_2) with recommended level of K (K_1) was almost equal to the diameter and height with watering at 90% depletion of available water level (M_0) in combination with double the recommended level of K (K_2). Similar results were recorded in other growth parameters such as number of leaves, leaf area etc. As would be expected better growth resulted in higher total fresh and dry weights and higher relative growth rate of the trees in combination with more soil moisture and less K or low soil moisture and more K.

Assessment of root length and spread made at the end of 12 months after commencement of the experiment showed a significant interaction between applied K and soil moisture content. It appears that under water stress conditions application of K has improved root growth.

Data on leaf K and Mg contents also indicated a significant interaction between applied K and moisture levels.

Plant physiological measurements *viz* stomatal conductance, transpiration rate, relative water content, leaf water potential, osmotic potential, assimilation rate and micro-tapped yield indicate a better plant water status in K sufficient rubber plants. The influence of high levels of added K, in overcoming moisture stress effects, was also recorded.

Key words: *Hevea brasiliensis*, water relations, potassium

INTRODUCTION

Drought resistance in plants could result from an inherent capacity to withstand internal moisture stress. Alternatively it could also result from a mechanism which enables plants to minimize transpiration by an osmoregulatory process during the time of stress. An important physiological characteristic that enables a plant to conserve soil water and survive soil moisture stress is a reduction in stomatal and cuticular transpiration. Stomatal closure in response to moisture stress is a powerful mechanism for reducing stomatal transpiration. Regulating transpiration and improving water use efficiency of plants could increase and stabilize yields and be of economic value with respect to the survival of the plants under stressed conditions (Lindhauer, 1989).

A major factor influencing crop yield, is the amount of moisture available to the crop during the growing season. Adequate fertility is important in getting the most out of the moisture that is present in the soil. It is well documented that an adequate supply of K has an important role in the water relation of plants (Hsiao and Lauchli, 1985).

K involvement in plant physiology is extremely complex, because many of the important biological reactions require K. Adequate K in particular result in more turgid guard cells around the stomata. Stomata in plants low in K are sluggish in opening and closing and lose considerable amount of their capacity to respond to rapidly changing environmental conditions. Earlier workers have noted that better K nutrition tended to increase water content of the tissue (Mengel and Kirkby, 1980). With low soil moisture content the availability of K is low because of the thin water film around the soil particle. With thicker water films or with higher soil moisture content K can diffuse more readily within the soil.

K is one of the major nutrient elements required and taken up in large amounts by *Hevea* besides N and P (Yogaratnam and Weerasuriya, 1984). Plants cannot achieve maximum growth and yield without K, nor can the function that K performs be fully carried out by another substituting element. Since irrigation is not feasible in most of the rubber plantations in Sri Lanka, application of K may be of importance in overcoming moisture stress on growth and yield. The present investigation was therefore undertaken to study the influence of K nutrition in overcoming stress effects in *Hevea*.

MATERIALS AND METHODS

A pot experiment was conducted to study the effects of four levels of moisture and three levels of K on the performance of *Hevea* plants.

Four levels of moisture (M) were;

M_0 - Watering at 90% depletion of available water
M_1 - Watering at 70% depletion of available water
M_2 - Watering at 50% depletion of available water
M_3 - Watering at 30% depletion of available water

Three levels of potassium (K) were;

K_0 - No K
K_1 - Recommended dosage (33g of K/plant/year)
K_2 - Double the recommended dosage (66g of K/plant/year).

Maintaining the four levels of moisture throughout the experiment was done using a neutron meter. To get the correct radius of measurement or the sample size for the neutron meter method, large cement barrels of diameter 86 cm and depth 120 cm were used. This was done on the basis of guidelines furnished by the user manual provided with the Neutron Meter used in this study, supplied by Messers Troxler International Ltd. Each barrel was lined with two layers of thick polythene sheets. Barrels were buried in the soil leaving a 10 cm rim above the ground level and filled with soil of the *Agalawatta* series (Silva, 1964), sieved with a one-inch mesh sieve. These barrels were buried in a plant house with a transparent roof and cloth curtains around it to prevent interference by rain water during heavy rainy periods.

One-whorled, green budding polybag plants of clone RRIC 100 were planted and N, P and Mg fertilizer were applied uniformly to all pots according to the RRI recommendations. Growth measurements, plant nutrient contents, plant physiological measurements and micro-tapped yield were recorded periodically.

RESULTS

Assessment of plant diameter and height made at the end of 3, 6, 9 and 12 months after commencement of the experiment, showed a significant interaction ($P<0.001$) between applied K and soil moisture content (Fig. 1). It appears that increasing the level of applied K to double the normally recommended level would tend to retard the rate of girthing of rubber plants, under no stress condition. It was also noted that the plant diameter and height at M_2 level with K_1 (recommended level) was almost equal to the diameter and height at M_0 level in combination with the K_2 level. This tendency was more prominent from the 6th month after planting. A significant interaction ($P<0.001$) between applied K and soil moisture content on number of leaves was also observed (Fig.2), and application of K at K_1 level significantly ($P<0.05$) increased the leaf area of rubber plants (Table 1). Leaf area data further showed that with more soil moisture the leaf area increased significantly ($P<0.01$).

Table 1. *Effect of different moisture (M) regimes and potassium (K) levels on leaf area*

Treatment	Leaf area (m^2)
M_0	1.347
M_1	1.609
M_2	1.715
M_3	2.195
$LSD_{0.05}$	0.427
K_0	1.414
K1	1.808
K_2	1.927
$LSD_{0.05}$	0.370

Assessment of root length and spread made at the end of 12 months after commencement of the experiment, showed a significant interaction ($P<0.001$) between applied K and soil moisture content. It appears that under water stress conditions, application of K has improved the root growth (Fig. 3).

A quadratic response ($P<0.001$) was observed with application of K, on total fresh and dry weights and relative growth rate (RGR) at M_3 and M_2 levels of soil moisture where there was an increase in total dry weights and RGR with K_1 level; and when K was increased to K_2 level, a reduction in RGR was observed. However, an opposite trend was observed in RGR at M_1 and M_0 levels (Fig. 4 and 5).

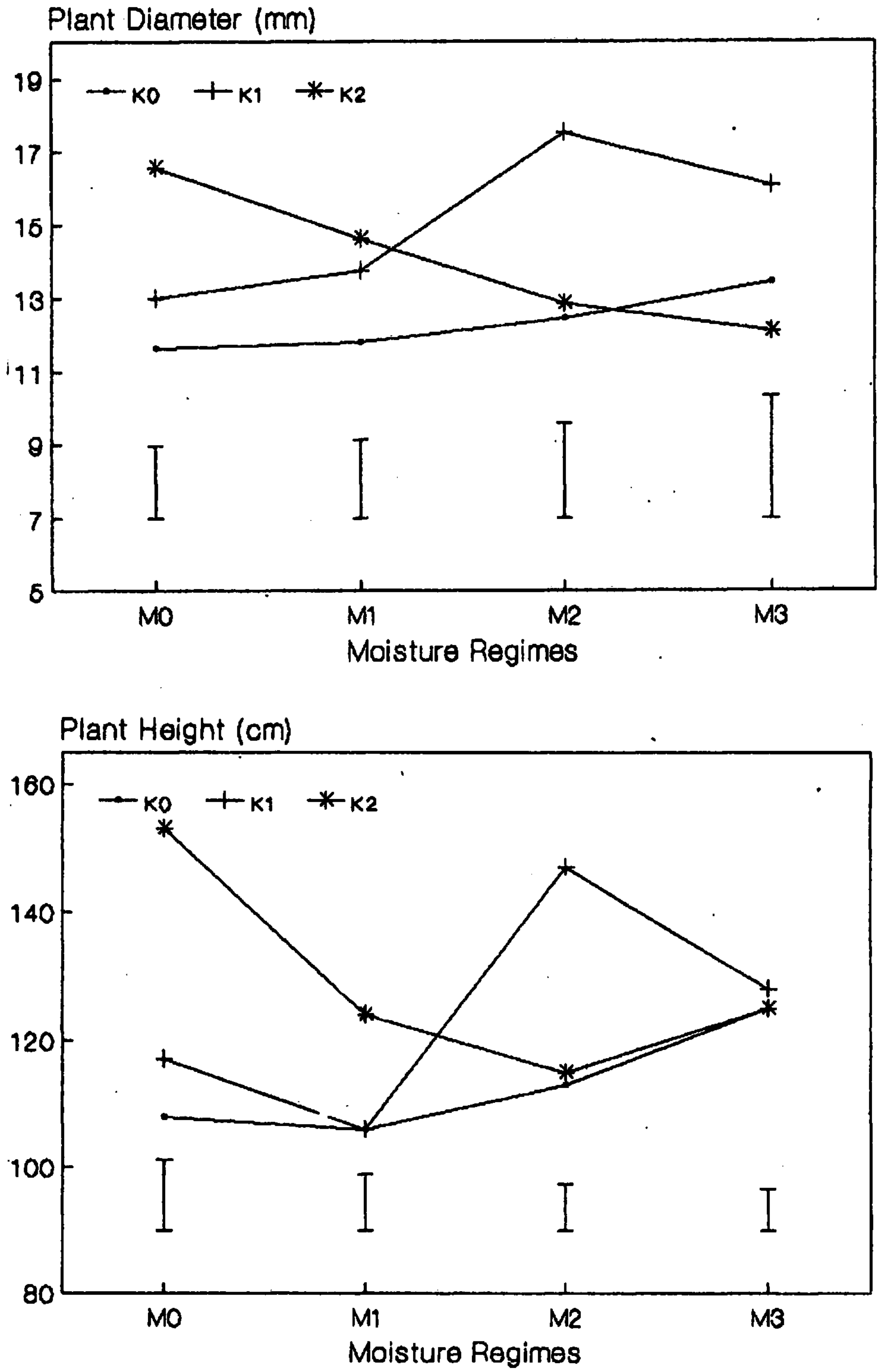


Fig. 1 Effect of different soil moisture regimes and potassium levels on plant diameter and height.

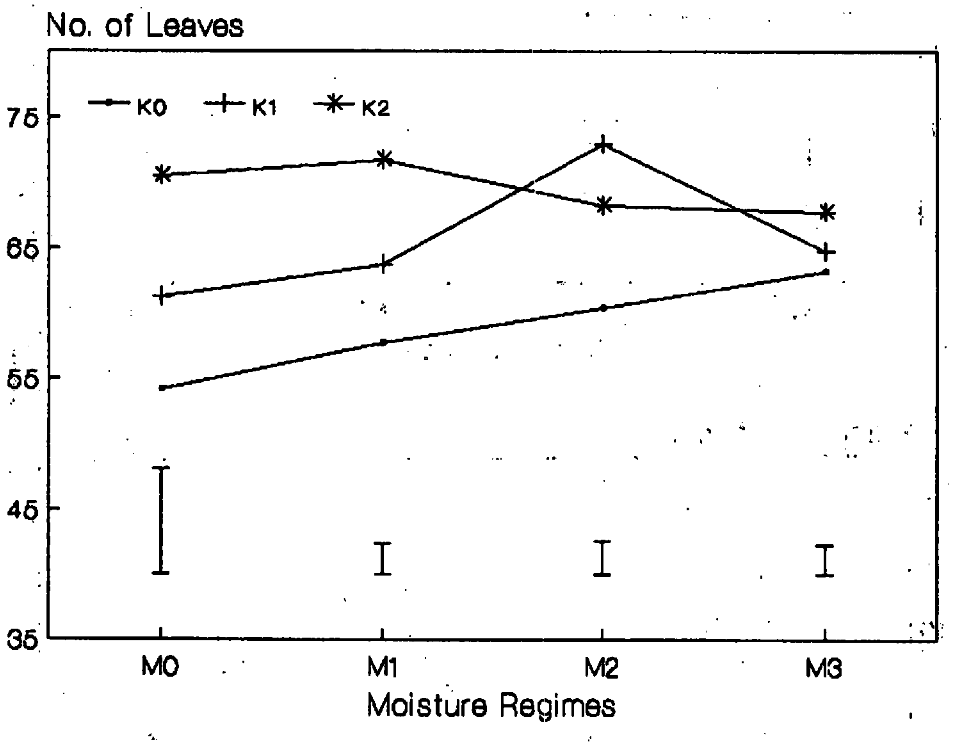
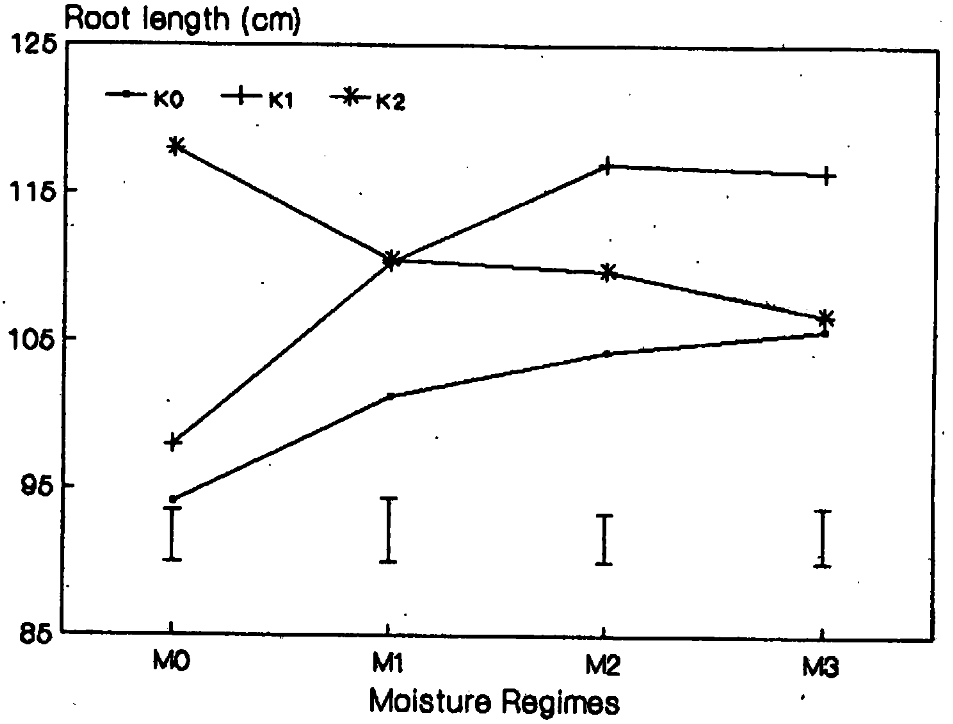


Fig. 2 Effect of different soil moisture regimes and potassium levels on number of leaves.



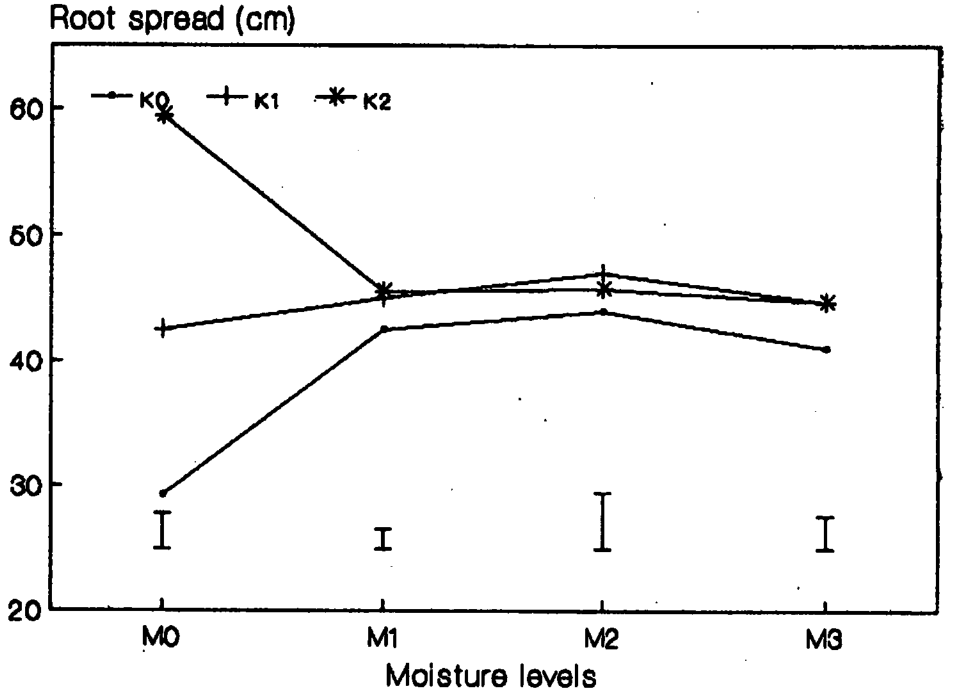


Fig. 3 Effect of different soil moisture regimes and potassium levels on root length and spread

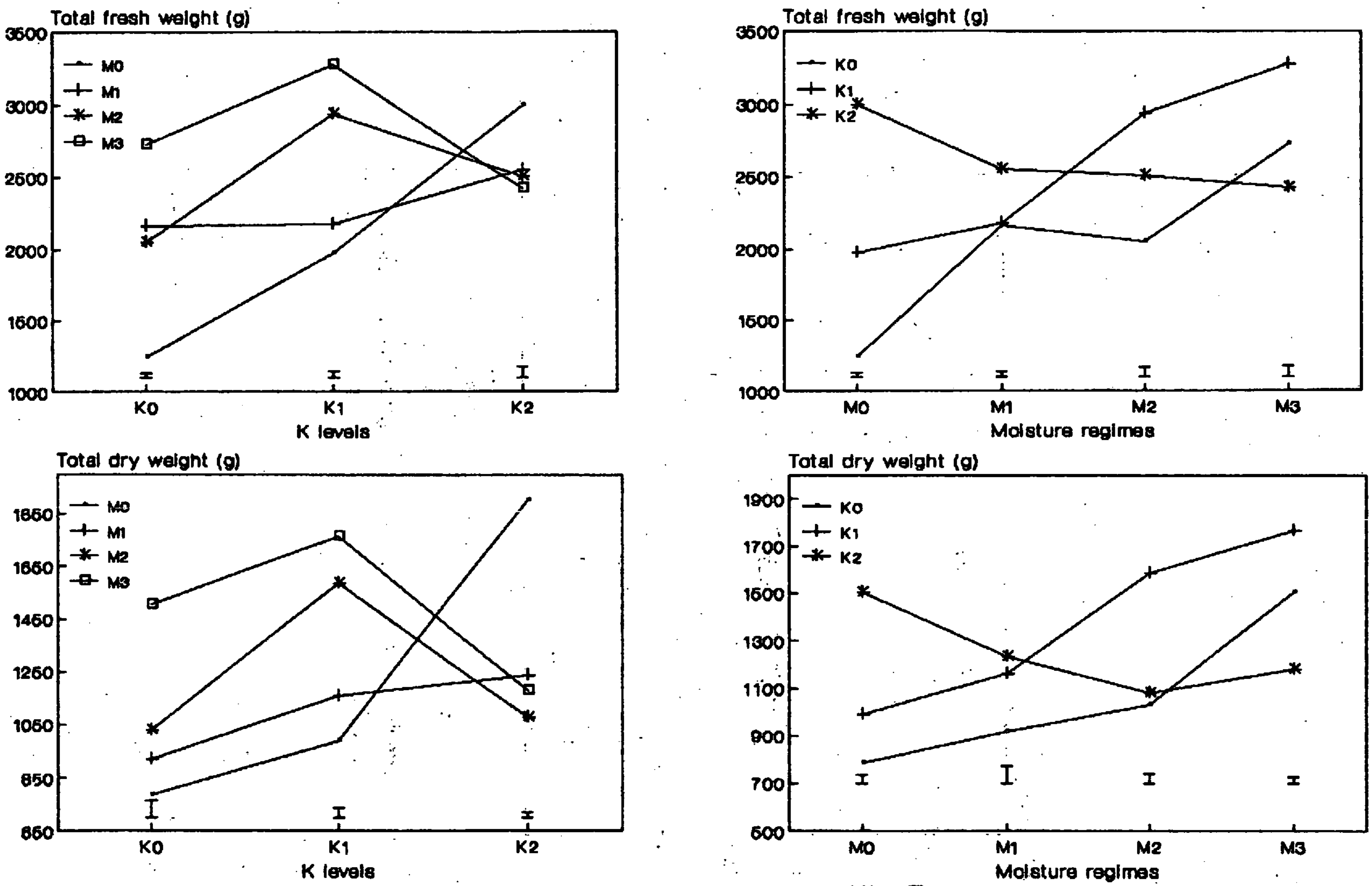


Fig. 4 Effect of different soil moisture regimes and potassium levels on fresh and dry total weight.

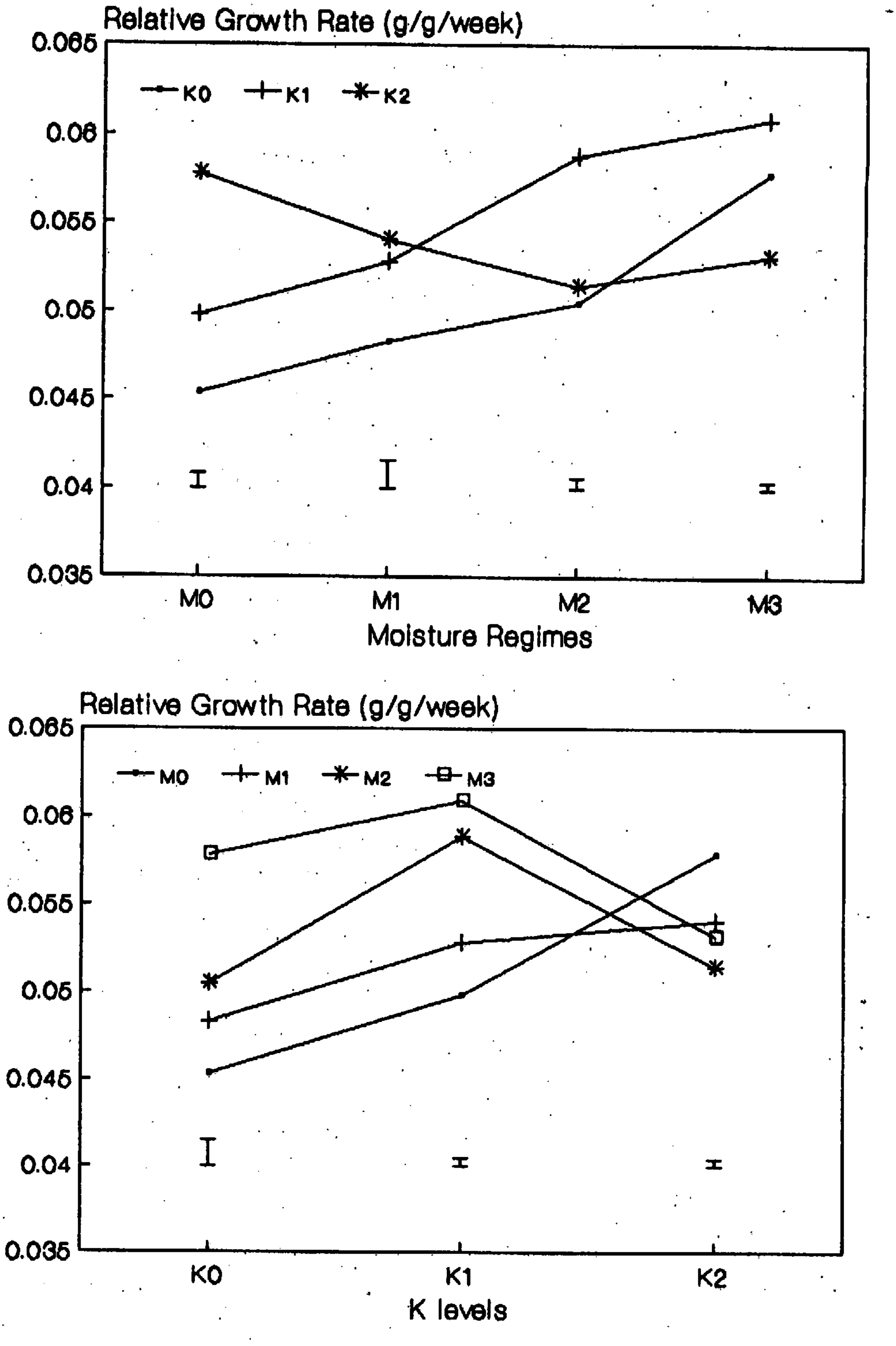


Fig. 5 Effect of different soil moisture regimes and potassium levels on relative growth rate.

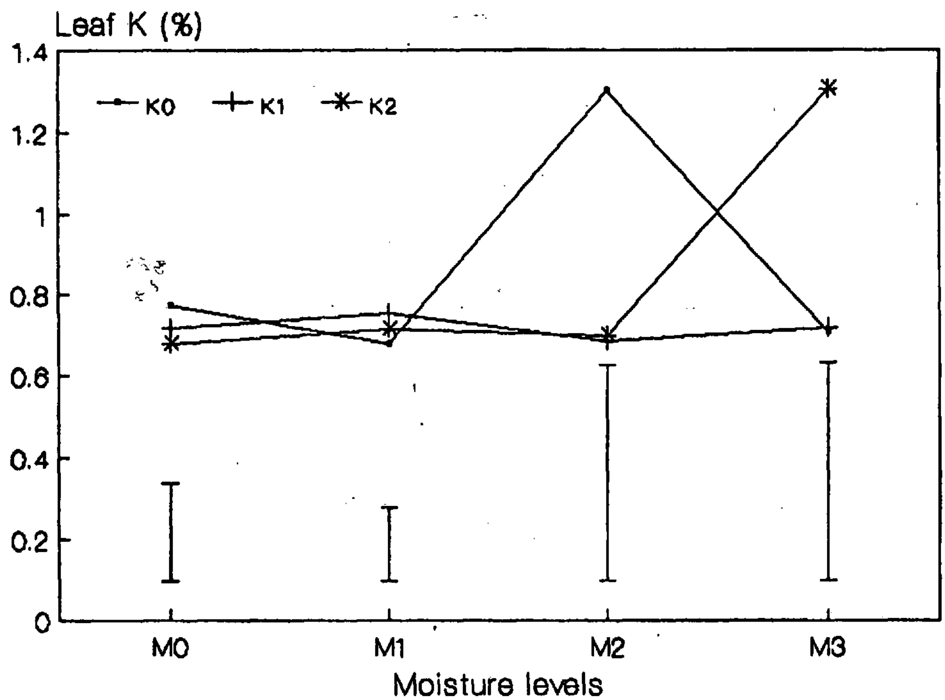


Fig. 6 Effect of different soil moisture regimes and potassium levels on leaf K content.

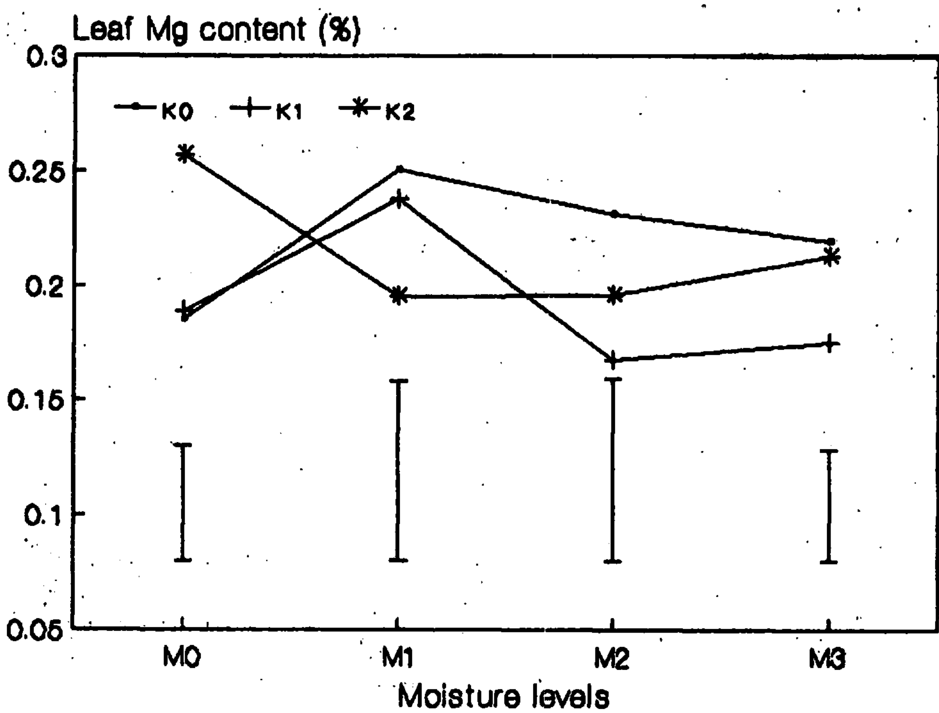
There was a significant interaction ($P<0.01$) between applied K and different levels of soil moisture on leaf K content of *Hevea* plants. A marked increase in leaf K content was observed at K_1 level with the increase in soil moisture level from M_1 to M_2 and at K_2 level from M_2 to M_3 (Fig 6). A significant interaction ($P<0.05$) was also observed between applied K and moisture content on leaf Mg content (Fig.7).

There was a significant interaction ($P<0.001$) between applied K and different levels of soil moisture on stomatal conductance and transpiration rate (Fig.8). Data on relative water content and leaf water potential indicated that there is a significant interaction ($P<0.05$) between applied K and moisture regimes (Fig.9). A significant interaction ($P<0.05$) between applied K and soil moisture was observed on osmotic potential (OP) where in the absence of K there was no difference in OP with the increase in soil moisture level, but at K_1 and K_2 levels a reduction in OP was observed with the increase in soil moisture content (Fig. 10). Assimilation rate and micro-tapped yield showed a significant interaction ($P<0.001$) between applied K and soil moisture contents (Fig.11).

DISCUSSION

K is one of the major nutrient elements required and taken up in large amounts by *Hevea brasiliensis*, beside N and P (Yogaratnam and Weerasuriya, 1984). Plants cannot achieve maximum growth and yield without K, nor can the functions that K performs be fully carried out by another substituting element.

Another major factor that influences crop yield is the amount of moisture available to the crop during the growing season. Adequate fertility is considered important in getting the most out of the moisture that is present. This study showed clearly that plants with adequate supply of water were superior to plants under stress conditions with regard to their growth. An adequate supply of K is known to play an important role in water relation of plants (Hsiao and Lauchli, 1985). The results of this study therefore, seem to suggest that the higher soil moisture content increases the water uptake, and along with the water, nutrients are also taken up thereby increasing the growth of rubber plants. At the same time when the growth patterns in response to K application were compared, it was clear that growth increment due to the increase in soil moisture content was always greater with more K. It was further noted that the plant diameter and height with soil moisture at 50% field capacity with recommended level of K were almost similar to the diameter and height with soil moisture at 10% field capacity in combination with double the recommended level of K. However, it



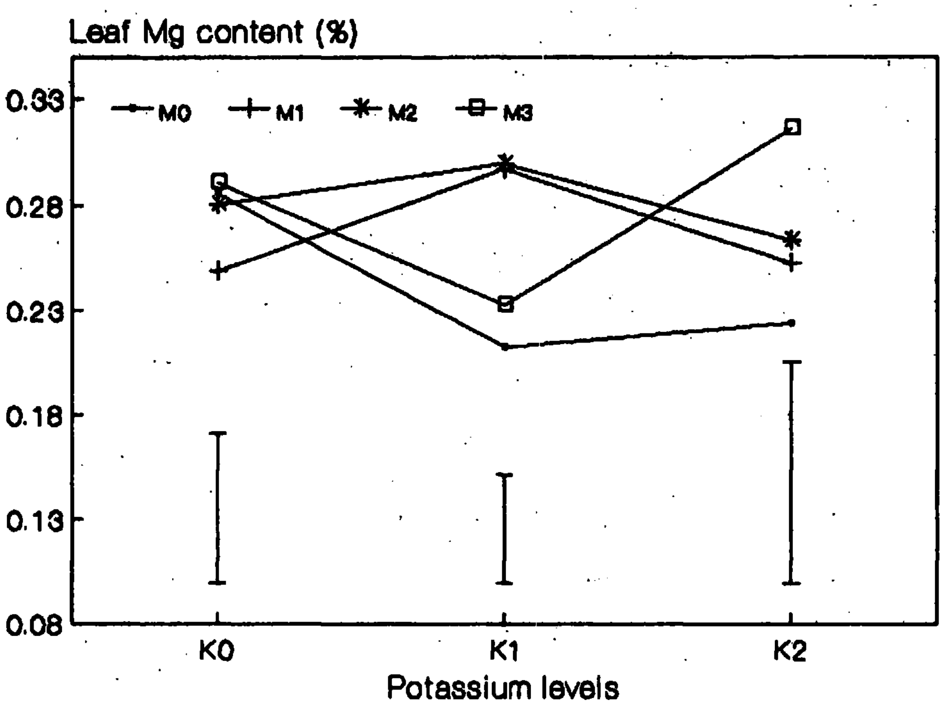


Fig. 7 Effect of different soil moisture regimes and potassium levels on leaf magnesium content.

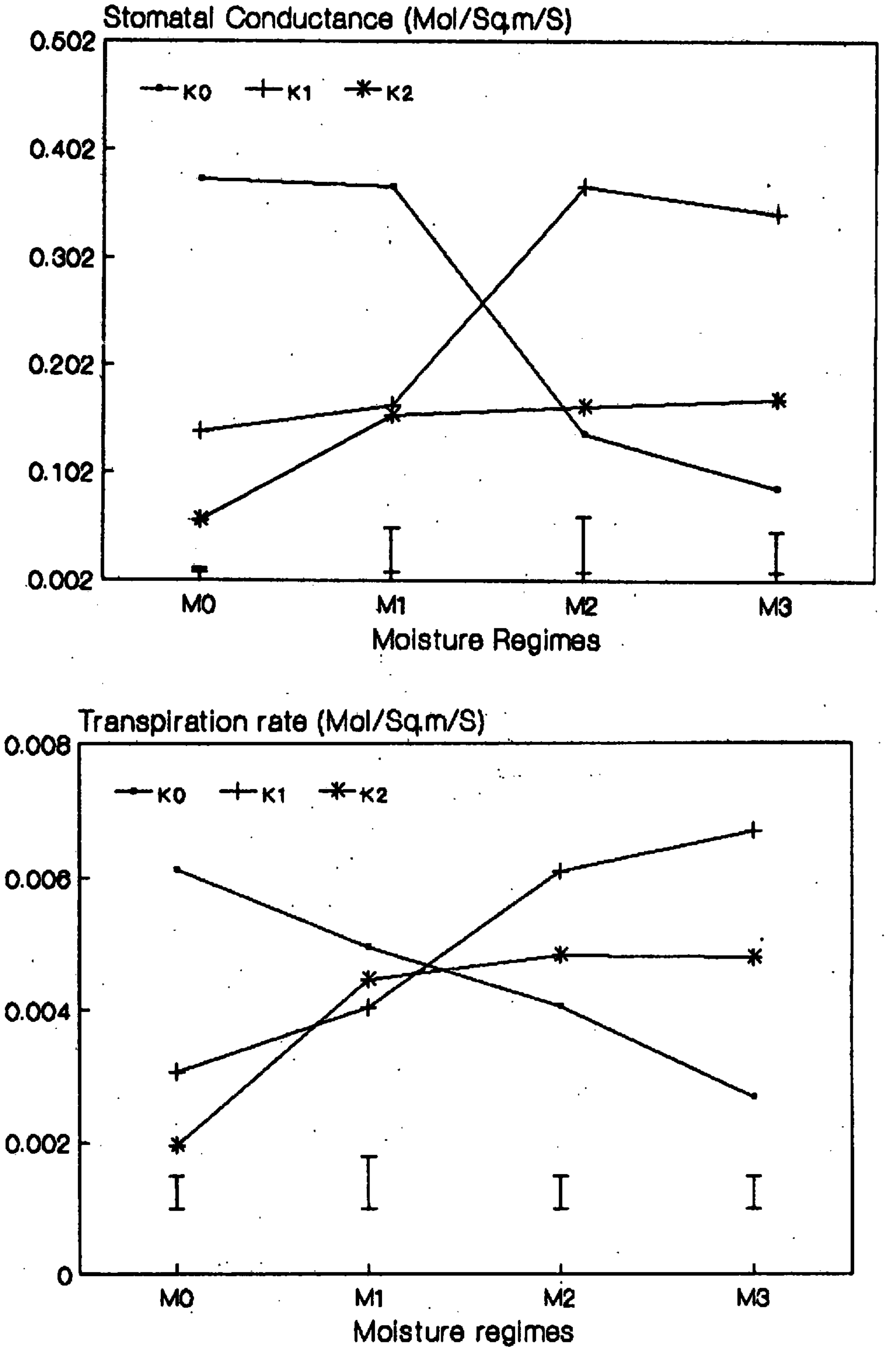


Fig. 8 Effect of different soil moisture regimes and potassium levels on stomatal conductance and transpiration rate.

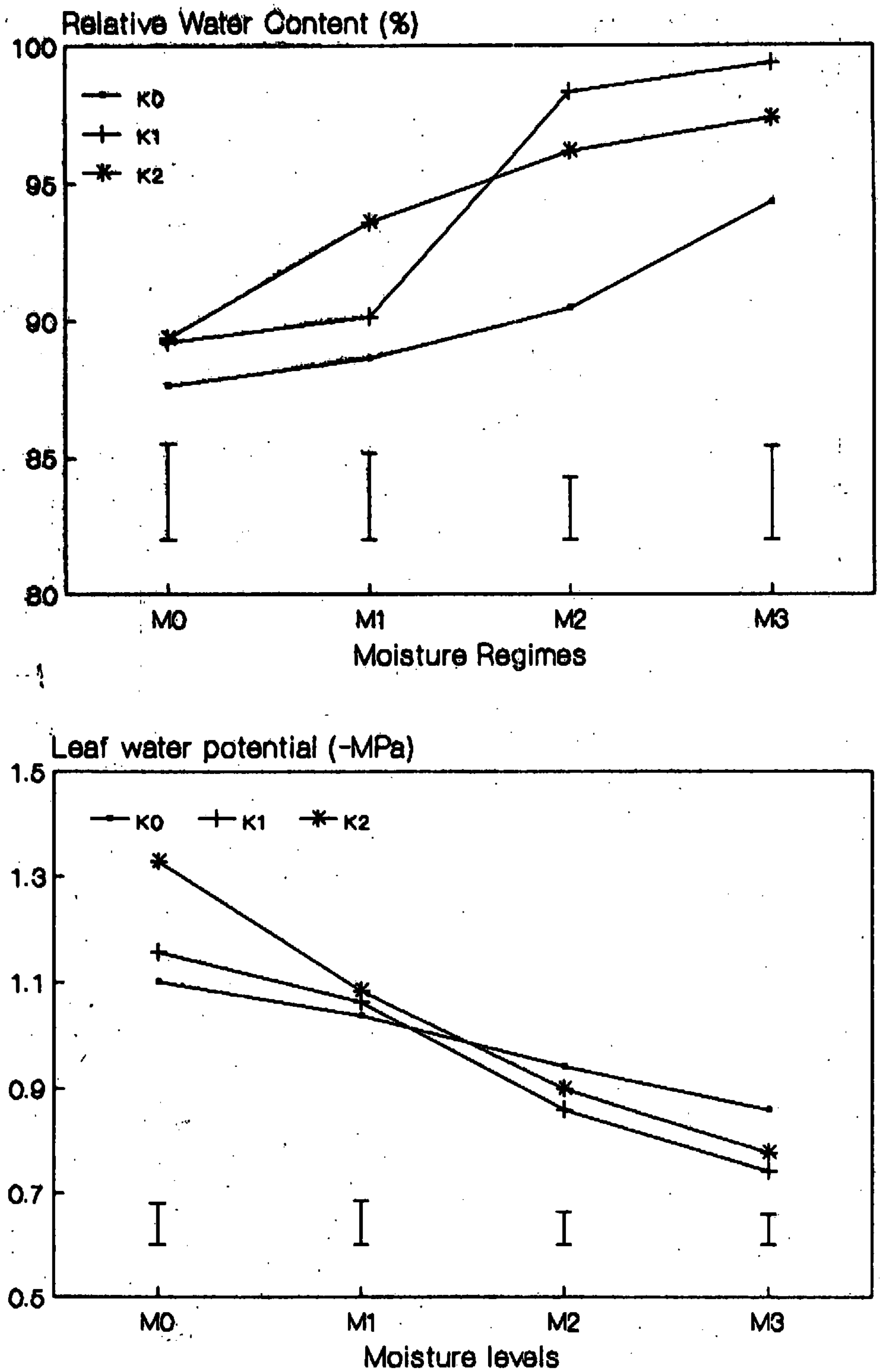


Fig. 9 Effect of different soil moisture regimes and potassium levels on relative water content and leaf water potential.

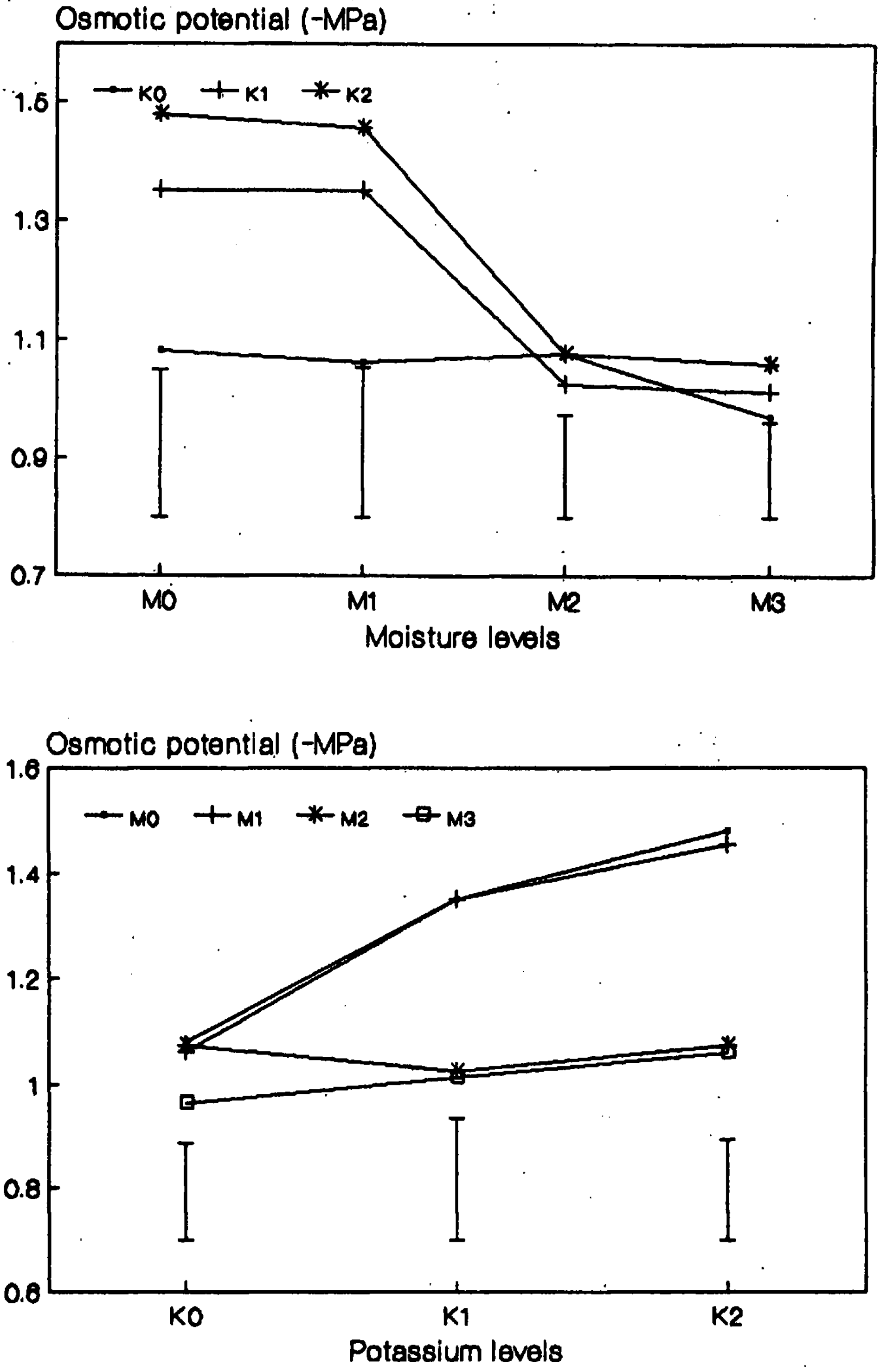


Fig. 10 Effect of different soil moisture regimes and potassium levels on osmotic potential.

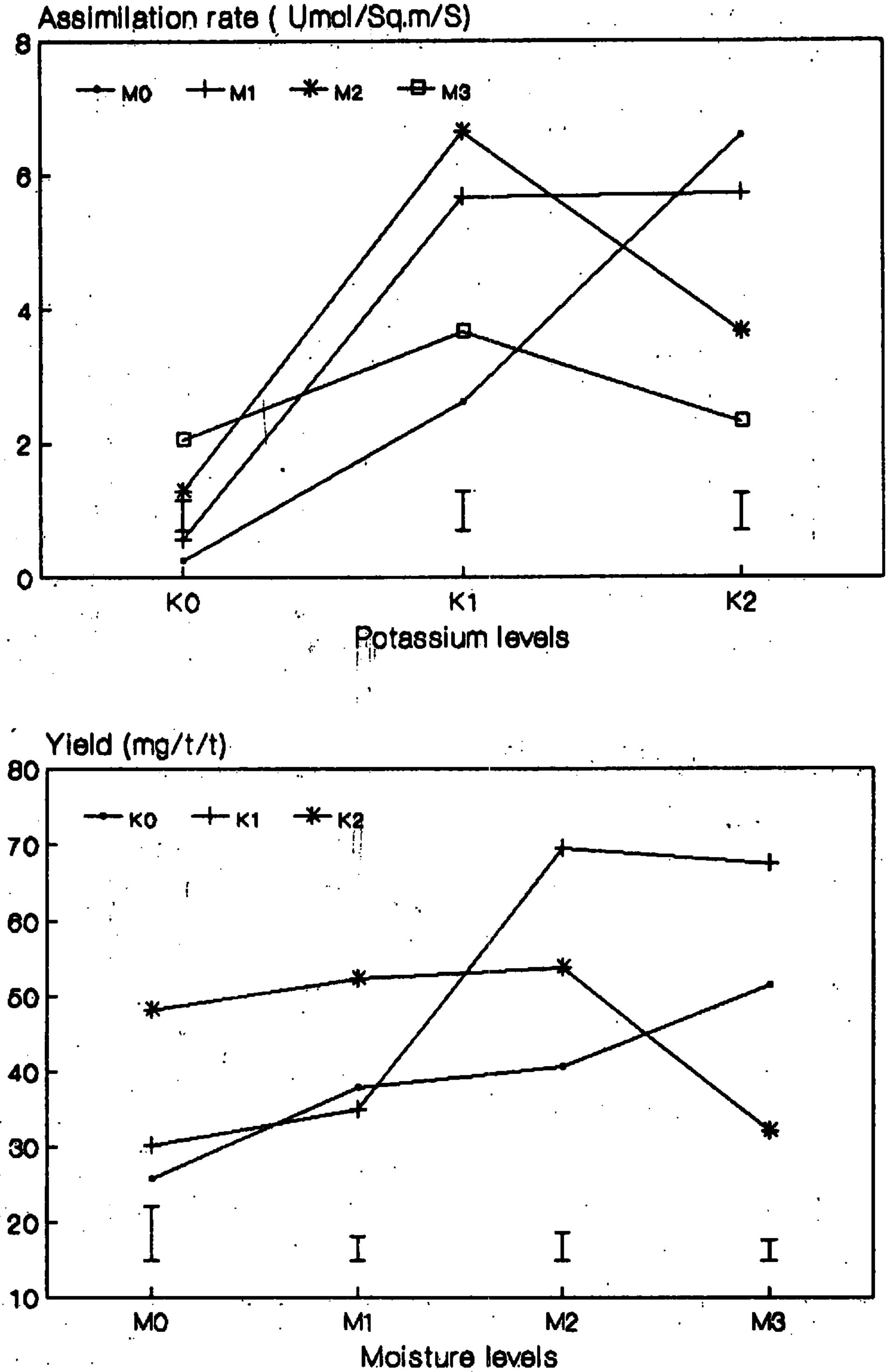


Fig. 11 Effect of different soil moisture regimes and potassium levels on assimilation rate and yield.

also appears that increasing the level of applied K to twice the original would tend to retard the rate of growth of plants. Similar results were also recorded in growth parameters such as, number of leaves, leaf area *etc*. As would be expected, better growth resulted in higher total fresh and dry weights of the trees in combination with either more soil moisture and less K or with low soil moisture and higher K. The trees with these combinations carried a much denser canopy, which is also associated with greater vigour of the trees. This effect is possibly due to greater mobility of soil K under moist conditions and also due to the availability of higher level of K in soil which is in line with the finding of the Mengel and Von Braunschweigh (1972) who have reported that at low soil moisture tension, about 17 mg/100g exchangeable K was needed to produce 6g of dry matter compared with 46 mg at high soil moisture tension.

Data on the influence of soil moisture on root growth indicated, that moisture stress reduces root growth and thereby the efficiency with which roots absorb soil nutrients. Taylor and Gardner (1983) have reported that the increasing root penetration is associated with increasing soil moisture, and the roots are shorter and thinner under high soil moisture stress conditions.

Moreover, some root growth measurements made, indicated that root penetration was improved with added K. It also seems to suggest that adequate nutrient supply encourages root proliferation and deeper penetration so that water can be taken up from depth which is obviously advantageous under stress condition. Edward (1981) found that maize roots penetrated 60 cm deeper when receiving K fertilizer, giving access to an extra 10 cm of water. It has been suggested that efficient water uptake from the soil and its' transport upwards are more important than stomatal conductance in determining drought resistance by sorghum and cotton (Ackerson and Krieg, 1977).

Leaf analysis provides abundant evidence of the uptake of K and Mg in relation to different levels of moisture and K. It was noted that the leaf K content was greater at higher soil moisture levels. It seems to suggest that better soil water status may improve the K uptake of rubber plants. The positive relationship between soil moisture and K uptake has been demonstrated by many authors (Beringer, 1983; Mackey and Barber, 1985). They concluded that at very low soil moisture the continuity of water films surrounding the soil particles tends to break, resulting a low rate of K diffusion. Since K is transported towards the roots mainly through diffusion, adequate soil moisture is an important prerequisite for K availability (Saxena, 1985). Therefore, when soil moisture is limited, addition of higher amounts of mineral K would help to accelerate the diffusion process towards the roots which in turn would improve the K status of the plant. It seems possible that plant K uptake is mainly controlled by the K concentration of the soil solution and the soil moisture content. Therefore, application of K and maintenance of proper soil moisture level may improve the available K to the rubber plant. However, this has to be done with caution as higher levels of applied K can even suppress Mg uptake as indicated by low leaf Mg concentrations supporting earlier reports and emphasizing the vital importance of balanced nutrition (Yogaratnam and Weerasooriya, 1984; Yogaratnam and De Mel, 1985).

This study has shown that most of these results are consistent with the physiological parameters made, and K has a clear influence on the water status of rubber plants. It is known that K plays a specific role in most plant species; in opening and closing of stomata – a role which cannot be played by any other cation (Mengel and Kirkby, 1981), and that better K nutrition tended to increase the water content of the tissue (Beringer, 1982). The data presented show a dual-phased effect on stomata in rubber plants, the first is a water reversible effect and the second is a K activated effect. According to the results, stomatal conductance and transpiration rate of K sufficient rubber plants were decreased with increase in soil moisture stress. However, in the absence of K, stomatal conductance was greater at 10% field capacity losing more water from the plant. It seems to suggest that K sufficient rubber plants appear to close stomata and reduce transpiration more readily than K deficient plants. It is possible that water stress in plants low in K, develops due to the sluggish opening and closing of stomata and to their low capacity to respond to rapidly changing transpirational conditions. It is well documented that stomatal opening is affected by accumulation of K ions in the guard cells (Outlaw, 1983). Trolldenier (1971) and Skogley (1976) showed that barley, well supplied with K, closed its stomata in 5 minutes and so reduced water loss, while K deficient barley required 45 minutes. It may be assumed that K deficient plants had neither exhausted their soil water intensively nor regulated their stomata efficiently.

It was further noted that water deficit caused a large and progressive decrease in leaf water potential in K sufficient rubber plants. The positive correlation of leaf water potential the moisture levels, suggests some direct relation with the moisture itself rather than an indirect effect by K concentration. This is concomitant with the increased osmotic potential of K sufficient plants with increasing soil moisture level, whereas osmotic potential of K deficient plants remained fairly constant. This study also showed clearly that with stressed plants there was a decrease in osmotic potential with the increase in K level. Decreased osmotic potential in K sufficient plants which resulted in maintenance of turgor, was most likely due to a increase in the concentration of osmotically active cell K^+. In most crop species, K^+ makes a major contribution to the osmotic potential of the cell sap (Lauchli and Pfluger, 1979).

Measurement of relative water content of leaves under the influence of decreasing water availability in the soil revealed significantly higher values i.e. a better water status of the leaf tissues for K sufficient plants. These results seem to suggest that K_2 plants under water stress maintain a higher turgor potential than K deficient plants.

According to this study the early closure of stomata in K sufficient plants should slow the diffusion of CO_2 into the leaves, thus reducing photosynthetic productivity. However, it is important to note that micro-tapped latex yield always remained high in K sufficient plants than in K deficient plants. It may therefore be concluded that even under conditions of restricted water availability, K sufficient plants are capable of improved production of assimilates. This also seems to suggest that irrespective of reduced stomatal conductance more dry matter is produced and more assimilates are made available for latex production in K sufficient plants than in K deficient plants. This is in agreement with the results obtained by Lindhauer (1989), which clearly shows the need for adequate K supply and K controlled water balance in yield production of field beans.

This study highlights the effect of soil moisture stress and K application on growth, yield, K uptake and water relations of rubber plants where the compensating effects of high levels of added K in overcoming moisture stress effects are clear. An important observation that emerges from this study is that application of K especially at double the recommended level, might result in increased water use efficiency under stress conditions and thereby increase growth as well as yield of *Hevea*.

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