

EFFECT OF SHADE, WATER SUPPLY AND NITROGEN ON THE DISTRIBUTION OF MINERAL NUTRIENTS AND TOTAL CARBOHYDRATE RESOURCES IN YOUNG TEA (*CAMELLIA SINENSIS* (L.) O. KUNTZE)

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Mineral nutrient contents and total carbohydrate resources of young free-growing tea plants of clone TR1 2025 grown in pots in a glasshouse at sub-optimal and adequate levels each of light, water supply and nitrogen and their combinations were determined. In general, plants supplied with adequate nitrogen had a greater per cent of N and Mn in the leaves, stems and roots, those with adequate water had more P, K, Al and Mn in leaves, P, K and Ca in stems and Mg, Al and Mn in roots and the whole plant. Shaded plants had a greater per cent of nutrients in the shoots except Mg. At both levels of nitrogen, more nutrients accumulated in the plants when unshaded and fully watered. At any level of water supply or nitrogen, less accumulated in shaded plants. More nutrients were seen in actively growing shoots of unshaded plants.

The per cent and total carbohydrate resources were less affected by nitrogen. A greater per cent of resources were seen when water was limiting. A greater per cent and total resources were seen in unshaded plants which in the stem bark and roots were double those in the stem wood. Overall more resources accumulated at adequate light and water supply. While the bark had equal proportions of soluble sugars, starch and higher polysaccharides the wood had less starch. The roots had more soluble sugars.

The main effects and interactions of light, water supply and nitrogen on mineral nutrient contents and total carbohydrate resources have been discussed from data derived from their respective analyses and the dry weight components of the plant.

INTRODUCTION

Mineral nutrient analysis of plant tissues is now considered indispensable in investigations of nutritional problems and for use as a guide in the determination of the nutrient/fertilizer requirements of plants, amongst others (Bould and Hewitt, 1963; Epstein, 1972). The theoretical basis of plant analysis has been the subject of much discussion (Thomas, 1937; Goodall and Gregory, 1947; Lundergardh, 1951; Ulrich, 1952; Wallace, 1961; Smith, 1962; Prevot and Ollagnier, 1963). Analysis of the plant provides a summation of the effects of all the environmental factors and is the best indicator of nutrient availability. In the practical application of the results of mineral nutrient analysis the usual method is to set a "critical nutrient level" below which the nutrient is regarded as deficient.

Much work has also been done on reserve metabolism as carbohydrates form the major component of plant tissues (Priestley, 1962). However, in spite of several studies made on the chemical nature of the reserves in tree species, the method of accumulation and utilization, knowledge in this field is far from complete.

Whilst the literature on temperate herbaceous as well as perennial plants is voluminous, the work on tropical plants, in particular the perennials, is relatively scanty (Goodall and Gregory, 1947). Studies on the effect of some factors, including

forms of nitrogenous fertilizers and of age of leaves, on their nutrient contents have been reported on tea (Hasselo, 1965; Bhavanandan and Sunderalingam, 1971).

In a previous paper (Kulasegaram and Kathiravetpillai, 1976) the effects of shade, water supply and nitrogen were studied in respect of the growth of young tea plants. In this paper, we report the results of the effects of the same factors on the uptake and distribution of mineral nutrients and of the accumulation of total carbohydrate resources.

MATERIALS AND METHODS

Experimental details were similar to those reported previously (Kulasegaram and Kathiravetpillai, 1976). The lower levels of the three factors were deliberately chosen from previous experience to be sub-optimal for good growth while the upper levels provided sufficient amounts for vigorous growth. Samples for analysis of mineral nutrients and total carbohydrate resources were taken from additional plants of the same clone, TRI 2025 maintained for this purpose under the same conditions. Leaf and stem samples were taken from both the main and side shoots. The components of the plants were separated, oven-dried, ground and sealed in polyethylene bags and used for analysis. Mineral nutrient analysis was done in respect of N, P, K, Ca, Mg, Al and Mn by employing standard analytical techniques. Total carbohydrate resources were determined in the root and stem samples by the method of Priestley (1962) with slight modifications (Kandiah, 1971). The stem samples were separated into the bark and wood and analysed separately. In addition, the mineral nutrient content of buds, first expanded leaf, bud plus first two leaves and of 5 cm internode lengths below the buds of unshaded active and dormant shoots were also determined. The same components except the first leaf were also analysed in unshaded shoots just commencing active growth.

RESULTS

The percentage mineral nutrients, the dry weights and the carbohydrate resources of the different components of the plant are presented in Tables 1, 2 and 4 respectively. The main effects of light intensity, water supply and nitrogen and their interactions in respect of the accumulation and distribution of mineral nutrients and of the accumulation of carbohydrates in the plant have been obtained from the above Tables.

Effect of level of shade, water supply and nitrogen on mineral nutrient contents

Effect of nitrogen

In general, plants supplied with adequate nitrogen had a greater per cent of N and Mn in the leaves, stems, roots and plant while Al was greater in plants given restricted nitrogen (Table 1). The effect of the levels of nitrogen showed that a greater percentage of N, P, Ca, Mg and Mn were present in the leaves, equal amounts of K were apportioned between the leaves and roots while more Al was found in the roots.

Effect of water supply

When the water supply was increased there was a greater per cent of P, K, Al and Mn in the leaves, P, K and Ca in the stems and Mg, Al and Mn in the roots and plant (Table 1). The plant had also more K. Greater amounts of all nutrients tested were also present in the plant and its components when water supply was adequate (Tables 1 and 2). At both levels of water supply a greater percentage of N, P, K, Ca, Mg and Mn was seen in the leaves while more Al was present in the roots.

Effect of shade

Generally a greater per cent of nutrients were found in the leaves and stems of shaded plants while in the unshaded plants more nutrients were found in the roots and in the plant (Table 1). Greater amounts of all nutrients tested were present in the unshaded plant and its components (Tables 1 and 2). Considering the percentage distribution of nutrients within the plant, at both levels of shade, more nutrients were accumulated in the leaves. Among shaded plants most of the Mg was in the leaves while among unshaded plants Mg was equally divided between the components of the plant.

Effect of nitrogen and shade

No clear differences were noted in the percentage nutrients at both levels of nitrogen and of shade (Table 1). At the same level of nitrogen the unshaded plant as well as its components had greater amounts of nutrients (Tables 1 and 2). More nutrients were distributed in the leaves of shaded and unshaded plants at both levels of nitrogen, except that, in the unshaded plants, Al at both levels of nitrogen, and K at the higher level of nitrogen, were greater in the roots. Among the unshaded plants receiving adequate nitrogen the amount of K distributed in the roots was more than double that in the leaves.

TABLE 1 — *Mineral nutrient contents (%) of plants grown at different levels of light intensity (L_1 = low, L_2 = high), water supply (M_1 = low, M_2 = high) and nitrogen (N_1 = low, N_2 = high)*

Treatment combination	Mineral nutrients						
	N	P	K	Ca	Mg	Al	Mn
Leaves							
$L_1M_1N_1$	2.38	0.133	0.66	1.37	0.187	0.2688	0.075
$L_1M_1N_2$	3.15	0.095	1.13	0.96	0.202	0.2813	0.096
$L_1M_2N_1$	2.66	0.112	1.29	1.00	0.187	0.3563	0.112
$L_1M_2N_2$	3.08	0.104	1.38	1.07	0.190	0.3375	0.122
$L_2M_1N_1$	2.73	0.108	1.38	0.96	0.170	0.3313	0.092
$L_2M_1N_2$	3.15	0.079	0.75	1.40	0.200	0.3250	0.090
$L_2M_2N_1$	2.24	0.120	1.00	1.34	0.195	0.5000	0.084
$L_2M_2N_2$	3.08	0.124	1.01	1.15	0.180	0.4500	0.083
Stems							
$L_1M_1N_1$	1.12	0.087	0.78	0.50	0.112	0.1063	0.017
$L_1M_1N_2$	1.40	0.066	0.68	0.44	0.082	0.0750	0.023
$L_1M_2N_1$	1.05	0.079	0.84	0.53	0.090	0.0813	0.017
$L_1M_2N_2$	1.26	0.062	0.84	0.53	0.082	0.1188	0.021
$L_2M_1N_1$	0.91	0.045	0.41	0.38	0.140	0.0938	0.010
$L_2M_1N_2$	1.33	0.054	0.47	0.44	0.130	0.0500	0.013
$L_2M_2N_1$	0.77	0.074	0.69	0.44	0.122	0.0500	0.004
$L_2M_2N_2$	1.12	0.091	0.75	0.44	0.127	0.0500	0.005
Roots							
$L_1M_1N_1$	1.47	0.058	1.03	0.22	0.155	0.3438	0.009
$L_1M_1N_2$	1.96	0.066	0.91	0.19	0.150	0.3188	0.008
$L_1M_2N_1$	1.26	0.079	1.00	0.19	0.250	0.6625	0.013
$L_1M_2N_2$	1.68	0.083	0.84	0.16	0.162	0.6000	0.008
$L_2M_1N_1$	1.75	0.062	1.38	0.16	0.140	0.6875	0.012
$L_2M_1N_2$	2.03	0.062	1.50	0.19	0.150	0.5375	0.016
$L_2M_2N_1$	2.24	0.129	1.26	0.19	0.180	0.6588	0.012
$L_2M_2N_2$	1.82	0.046	1.43	0.16	0.130	0.5625	0.015

TABLE 2 — *Effect of light intensity ($L_1 = \text{low}$, $L_2 = \text{high}$) water supply ($M_1 = \text{low}$, $M_2 = \text{high}$) and nitrogen ($N_1 = \text{low}$, $N_2 = \text{high}$) on dry matter production (g) per plant*

<i>Treatment combination</i>	<i>Main + side shoot leaves</i>	<i>Main + side shoot stems</i>	<i>Roots</i>	<i>Plant</i>
$L_1M_1N_1$	2.35	1.34	1.19	4.88
$L_1M_1N_2$	2.29	1.52	1.35	5.16
$L_1M_2N_1$	2.52	1.54	1.25	5.31
$L_1M_2N_2$	2.46	1.53	1.25	5.24
$L_2M_1N_1$	2.72	2.01	3.86	8.59
$L_2M_1N_2$	3.29	2.09	3.94	9.32
$L_2M_2N_1$	11.11	9.69	9.25	30.05
$L_2M_2N_2$	12.48	9.65	9.43	31.56
LSD (P=0.05)	0.99	0.73	0.28	1.83

Effect of water supply and shade

Again no clear differences were seen in the percentage nutrients at both levels of water supply and of shade (Table 1). The accumulation of nutrients in the unshaded plant and its components were considerably enhanced when adequate water was supplied. A greater percentage of all nutrients were seen in the leaves of shaded and unshaded plants at both levels of water supply except for K and Al in the unshaded plants receiving restricted water supply.

Effects of water supply and nitrogen

There was no consistent trend in the percentage nutrients at both levels of water supply and nitrogen (Tables 1 and 2). At the same level of water supply there was more nitrogen in the plant and its components receiving adequate nitrogen. At the same level of nitrogen the plant and its components had more nutrients when adequate water was supplied. Among the nutrients, a greater percentage of N and Mn were found in the leaves while the other nutrients were mostly in the roots.

Effect of shade, water supply and nitrogen

Among leaves of shaded plants, at the same level of water supply, a greater per cent of nutrients were seen when adequate nitrogen was given, among roots when nitrogen was restricted while among stems more nutrients were seen only at the lower level of water supply and when nitrogen was restricted (Table 1). Among leaves of unshaded plants, at the same level of water supply more nutrients were seen when nitrogen was restricted, in the stems when adequate nitrogen was given while in the roots more nutrients were seen at the lower level of water supply when adequate nitrogen was supplied and at the higher level of water supply when nitrogen was restricted. Generally, in all treatments and irrespective of the levels of shade at the same level of water supply a greater per cent of nitrogen was seen in the plant and its components when adequate nitrogen was supplied. Among shaded plants and their components, no differences in the amount of nutrients were seen at the same level of water supply or of nitrogen (Table 1). Among unshaded plants more nutrients were always seen in the plant and its components at the same level of nitrogen but when water was not limiting. Irrespective of the nitrogen levels, a greater amount of nutrients were seen in the unshaded plant and roots at the lower level of water supply, in the leaves and stems at the higher level of water supply compared to the shaded plant and its respective components. The leaves of shaded and unshaded

plants had a higher percentage of nutrients at both levels of nitrogen and water supply except for K and Al which were generally higher in the roots of unshaded plants.

Mineral nutrients in apical components of active and dormant shoots and of shoots just commencing active growth

It will be seen that the apical components of active shoots had a greater percentage of N, P and K compared to those of dormant shoots or of shoots just commencing growth (Table 3). The calcium percentages were rather inconsistent but were generally more in dormant shoots.

TABLE 3 — *Mineral nutrient contents (%) of buds, leaves and internodes of unshaded active and dormant plants*

Plant organ	Mineral nutrients			
	N	P	K	Ca
Active buds	5.53	0.454	1.68	0.187
Dormant buds	3.36	0.249	1.06	0.656
Buds resuming growth	4.55	0.341	1.37	0.437
Active plant 1st - expanded leaf	5.11	0.399	1.43	0.156
Dormant plant - 1st expanded leaf	3.15	0.191	1.31	0.531
Active flush (bud + first two expanded leaves)	5.60	0.391	2.03	0.375
Dormant flush (bud + first two expanded leaves)	3.78	0.274	1.93	0.343
Flush from buds resuming growth (bud + first two expanded leaves)	3.43	0.158	1.46	0.718
5 cm of internode below active bud	2.87	0.237	1.65	0.750
5 cm of internode below dormant bud	2.52	0.249	3.00	0.437
5 cm of internode below bud resuming growth	2.03	0.179	1.25	1.06

Effect of level of shade, water supply and nitrogen on total carbohydrate resources Effect of nitrogen

No clear differences were seen between the levels of nitrogen on per cent as well as total carbohydrate resources (Tables 2 and 4). At both levels of nitrogen the per cent as well as the total resources were greater in the bark and roots which were generally more than double that in the wood. At each level of nitrogen the per cent and amounts of soluble sugars, starch and higher polysaccharides were found to be in equal proportions in the bark, while in the wood soluble sugars and polysaccharides were higher than starch but in the roots soluble sugars were higher than the other two components.

Effect of water supply

A greater per cent of resources were seen when the water supply was restricted (Table 4). More resources accumulated when there was adequate water (Tables 2 and 4). The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

Effect of shade

A greater per cent as well as total resources were seen in the unshaded plants (Tables 2 and 4). The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

Effect of nitrogen and shade

A greater per cent as well as total resources were seen in unshaded plants (Tables 2 and 4). Among unshaded plants more resources were seen when nitrogen was adequate. The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

Effect of water supply and shade

At both levels of shade a greater per cent of resources were seen when the water supply was restricted (Table 4). More resources accumulated in unshaded plants (Tables 2 and 4). Among unshaded plants resources were greater when water was adequate. The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

TABLE 4 — Carbohydrate resources (%) in stems and roots of plants grown at different levels of light intensity (L_1 = low, L_2 = high) water supply (M_1 = low, M_2 = high) and nitrogen (N_1 = low, N_2 = high)

Treatment combination	Soluble sugars	Starch	Higher polysaccharides	Total carbohydrate resources
Stem (Bark)				
$L_1M_1N_1$	25.43	22.08	24.13	71.64
$L_1M_1N_2$	26.56	23.86	22.47	72.89
$L_1M_2N_1$	23.52	18.42	21.79	63.73
$L_1M_2N_2$	21.80	21.65	20.24	63.69
$L_2M_1N_1$	21.20	27.19	22.16	70.55
$L_2M_1N_2$	35.21	22.84	24.32	82.37
$L_2M_2N_1$	20.81	26.41	24.56	71.78
$L_2M_2N_2$	32.93	21.65	26.14	71.72
Stem (Wood)				
$L_1M_1N_1$	13.11	7.49	9.52	30.12
$L_2M_1N_2$	13.78	7.99	9.86	31.63
$L_1M_2N_1$	11.86	5.71	9.58	27.15
$L_1M_2N_2$	11.64	6.71	6.33	24.68
$L_2M_1N_1$	14.28	8.26	14.80	37.34
$L_2M_1N_2$	15.98	10.28	15.18	41.44
$L_2M_2N_1$	8.68	5.21	10.06	23.95
$L_2M_2N_2$	10.04	4.63	8.84	23.31
Roots				
$L_1M_1N_1$	28.14	21.10	18.69	67.93
$L_1M_1N_2$	26.40	16.90	16.58	69.88
$L_1M_2N_1$	21.43	17.54	17.14	56.11
$L_1M_2N_2$	20.85	15.56	16.33	52.74
$L_2M_1N_1$	32.51	18.12	18.15	68.78
$L_2M_1N_2$	37.88	15.38	21.89	75.15
$L_2M_2N_1$	23.18	16.02	18.38	57.58
$L_2M_2N_2$	21.31	17.15	15.39	53.85

Effect of water supply and nitrogen

The per cent resources were less in plants receiving adequate water, being further depressed when adequate nitrogen was also supplied (Table 4). The total resources were greater in plants receiving adequate water (Tables 2 and 4). The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

Effect of shade, water supply and nitrogen

The per cent as well as total resources were generally more in unshaded plants (Tables 2 and 4). At the same level of shade, the per cent resources were less when adequate water and nitrogen were given. In the unshaded plants more resources accumulated with adequate water. The per cent and total resources in the bark and roots as well as the per cent and amounts of the components of carbohydrate resources showed a similar trend to that shown by the levels of nitrogen.

DISCUSSION

Plant tissue analyses are carried out either to document the range of mineral nutrients in different component tissues of healthy plants or to determine their critical levels below which deficiency symptoms and hence sub optimal growth will occur. They can also be used to select the particular tissue that will reflect the nutritional status of the plant which could be used as a guide to the fertilisation of crops. The results of such analyses are usually expressed on a percentage of dry weight tissue basis. Goodall and Gregory (1947) state that the method of expression should be selected which gives the best correlation between leaf nutrient status and growth. Coulter (1958) presents evidence of two series of oil palms, giving the same yield, that have similar analyses when results are expressed on dry matter basis, even where the soils are different. Smith (1962) finds no advantage in departing from the percentage method since the widest use of leaf analysis is in comparing concentrations of elements in plants grown under different conditions where the absolute concentration is of less importance than the difference between two values.

In the experiment reported here there did not appear to be any consistent trend amongst the treatments when the nutrient contents were expressed on per cent basis. Hasselo (1965) expressed the mineral nutrient content of tea leaves of increasing age on a per cent basis. He found that, out of 13 mineral nutrients studied, leaf N, K, P, Na, Zn and Cu decreased with increasing age of the leaves while leaf Ca, Mg, Al, Mn, Fe, B and Mo increased. He considered the leaf subtending the current pluckable shoot to be the better choice for standardization of his leaf sampling technique. In the present study since only representative samples of the components of the plant were taken, the samples would have been composed of young, immature as well as of mature tissues. Such variable tissues may have contributed to some of the inconsistencies noted when expressed on a per cent basis. The pattern of nutrient uptake appears to be variable and this is so because the phenomenon of nutrient uptake is so complex and dependent upon a combination of several factors. The attendant dangers of using variable tissue has been pinpointed by several workers (Thomas, 1937; Broeshart, 1954).

The effect of the levels of shade on the per cent nutrients shows some evidence of the leaves and stems of shaded plants having more nutrients (Table 1). The mineral composition of plant tissues is an unstable equilibrium influenced by internal and external factors. Some elements are present in high concentrations in

young tissue and are diluted as the tissue enlarges. Others are present in low concentrations in young tissue and gradually increase. The accumulation of dry weight dilutes all elements unless an influx of minerals offsets this effect. The fact that the leaves and stems of unshaded plants had relatively less mineral nutrients than those of shaded plants could be attributed to the nutrients being diluted due to the enhanced growth of the plants as reported earlier (Kulasegaram *et al.*, 1976). Sivasubramaniam (personal communication) studying the effect of shade on the yield and mineral nutrients of the foliage of different tea clones at two locations observed a general drop in the percentage nutrients in the high yielding unshaded plots.

Irrespective of the level of nitrogen, more nutrients accumulated in the unshaded plants. However, the most favourable effect was when, in addition, water was not limiting. It is significant that all combinations of water supply and nitrogen with shade elicited a poor response of nutrient accumulation. It has been shown previously (Kulasegaram *et al.*, 1976) that better plant growth takes place under unshaded conditions when moisture is not limiting and it is not improbable that the greater accumulation of nutrients in the plant is associated with such growth.

Analysis of the apical components of unshaded active and dormant shoots have clearly shown that actively growing shoots have higher levels of N, P and K (Table 3). This was also demonstrated in a previous study where it was shown that actively growing erect shoots had a greater nutrient content compared to inclined shoots which remained dormant frequently (Kathiravetpillai and Kulasegaram, 1981). It has been shown that unshaded plants receiving adequate moisture have a greater number of active phases of longer duration (Kulasegaram *et al.*, 1976). It is hence conceivable that the unshaded plants would have been in a position to accumulate more nutrients resulting in better growth compared to the shaded plants which remained dormant for correspondingly longer period.

The effect of the levels of the three factors in this study as well as their combinations have clearly demonstrated with few exceptions that the leaves were the chief repository of mineral nutrients in the plant. The effect of level of nitrogen and water supply showed some indication that the leaves and the stems had almost equivalent amounts of potassium. The effect of level of shade showed that 60% of the K accumulated in the leaves when the plants were shaded but under unshaded conditions 45% of the total uptake of K was found in the roots. Its distribution in the leaves or roots could be associated with the fact that K is a mobile element. A point of interest is that while 62.50% of the total uptake of Mg is found in the leaves under shaded conditions only 33.33% of the total uptake by unshaded plants is found in the leaves. This may probably be due to the fact that unshaded plants display a higher photosynthetic activity where Mg as a constituent of chlorophyll plays an important role. When shaded, leaves tend to become larger and darker green in order to arrest as much of the weak light that filters through and this may explain the high percentage distribution of this element in them. The effect of the level of the three factors studied have also shown an accumulation of Al in the roots. It is known that in plants sensitive to Al, both Al and phosphate accumulate in the roots. However, in this study there is an accumulation of Al in the roots but not of phosphorus. It may be that the tea plant being an Al accumulator is tolerant of high levels of Al.

Most workers studying the reserve metabolism of tea have considered the root as the principal storage organ (Tubbs, 1937; Nagarajah and Pethiyagoda, 1965). Kandiah (1971) examined the bark and wood of stems and roots separately in mature tea

as he considered these components important in view of the fact that new shoot growth arises directly on stem tissues. In this study, only the stem was separated into the bark and wood as the roots of young tea plants as used in this experiment had not shown sufficient growth. The results of the carbohydrate analyses have clearly demonstrated that even in young tea plants more carbohydrate resources are found in the bark (Tables 2 and 4). The total resources in the roots were less than the values in the bark while the resources in the wood were generally less than half the values in the bark as well as the roots. Kandiah (1971) has shown that the quantity of resources per unit residual matter is markedly more in the bark than in the wood and noted that an appreciable quantity of resources could be stored in the bark although this region is less bulky than the wood. It is possible that in tea, the reserves in the stem bark provide initial reserve requirements for new bud growth. He was also of the opinion that though the root stores more resources than the stem, such reserves appeared to be consumed mostly by the root system itself. However, Selvendran and Selvendran (1972) have presented evidence indicating that part of the root reserves of mature pruned tea plants are translocated to support new shoot growth along with resources found in the stem bark and stem wood during the period of recovery.

A previous study (Kulasegaram *et al.*, 1976) showed that best plant growth was obtained under unshaded conditions when adequate water and nitrogen were supplied. However, no differences in growth were seen at any of the levels of nitrogen used. In this study no differences in the carbohydrate resources were seen at the two levels of nitrogen but more total resources accumulated in the unshaded plants when water was not limiting. When light was not limiting more resources accumulated in the roots compared to that in the bark and wood. It is to be noted that irrespective of the light regime restriction of water supply resulted in a higher percentage of total resources. This is because at low levels of water, growth is poor and the percentage of resources appear to be high. It follows that the total resources accumulated will also be low as seen in this study. At higher levels of water supply, growth is rapid and the per cent resources are low but the total resources are high, an effect considerably enhanced when combined with adequate light. However, at low light intensity since the production of photosynthates are low it does not permit the accumulation of sufficient total resources even when water supply is adequate.

Considering the overall effects of all three factors, light intensity, water supply and nitrogen it is apparent that in the bark, wood and roots, irrespective of the level of shade a higher percentage of resources were seen when water was restricted but at adequate levels of nitrogen. The accumulation of total resources at low light intensities was less at both levels of moisture and nitrogen due to the low photosynthate production and poor growth. But at adequate light more total resources accumulated, an effect considerably enhanced when the water supply was adequate.

The effect of the major factors in this study on the per cent and amount of the components of carbohydrate resources showed that while, in general, the bark had equal proportions of soluble sugars, starch and higher polysaccharides, the proportion of starch in the wood was about half that of soluble sugars and polysaccharides. The roots had more soluble sugar compared to the other two components

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