CHAPTER VI

NUTRIENT ALLOCATION, ACCUMULATION AND USE EFFICIENCY

Resource allocation to different plant parts determines the fitness of the species. Plants show adaptive response in respect of nutrient uptake, water conservation, temperature tolerance, pollinator’s attraction, herbivore avoidance and seed dispersal etc. At some point of time in the life cycle, each of these traits makes a positive contribution towards the fitness of a species (Abrahamson and Caswell 1982).

The success of a plant in an environment can be predicted by relative apportionment of biomass and or nutrients in different parts (MacArthur and Wilson 1967; Gadgil and Solbrig 1972 and Abrahamson 1975). Species differences in morphology, physiology and behaviour arises from their divergent ability to deal with various environmental constraints and from their allocation patterns of nutrient and biomass (Cody 1966; Mooney 1972). Some plant species allocate high proportion of their biomass to the root allowing them to acquire more soil resources than plants with less root biomass, and thus making them superior competitors for soil nutrient resources (Tilman and Wedin 1991). By allocating more biomass to the root, plant species necessarily have less allocation to stem, leaf and reproductive buds and are unavoidably inferior in their ability to utilize light and to disperse seeds. The increased allocation in one trait necessarily causes a decrease in proportional allocation to other traits (Mooney 1972).

The present chapter deals with the allocation of N, P and K to shoot and root, their total accumulation in plant over time and use efficiency by the seedlings of Podocarpus
nerifolia, Acer laevigatum and Syzygium tetragonum under different light, soil water and nutrient environments.

Results

I. Effect of gap and understorey

Nutrient concentration

Nitrogen concentration in Podocarpus neriifolia and Syzygium tetragonum seedlings was higher in the forest understorey while that of Acer laevigatum seedlings recorded higher N concentration in gap. N concentration was higher in leaf followed by root and stem. It decreased significantly (p<0.05) with the increase in age of the seedlings of all three species (Fig. 6.1, 6.2 and 6.3).

Phosphorus concentration was higher in leaf followed by stem and root in all three species. Seedlings under forest understorey had significantly (P<0.01) higher P concentration than those in gap. The concentration decreased with age of the seedlings in both the situations (Fig. 6.4, 6.5 and 6.6).

The leaf had higher K concentration followed by stem and root in all three species both in gap and forest understorey. The concentration decreased with the age in Syzygium both in gap and forest understorey. In Podocarpus and Acer there was no significant difference due to seedling age and forest habitats (Fig. 6.7, 6.8 and 6.9).

Nutrient accumulation and its allocation pattern in root, stem and leaf

N accumulation (mg plant$^{-1}$) in all plant parts was significantly (p<0.01) higher in gap than the forest understorey in all species. Leaf accumulated maximum N followed by root and stem at both the places, and it increased with age of the seedlings (Fig. 6.10).
Fig. 6.1. Nitrogen concentration in different parts of *Podocarpus neriifolia* seedlings in gap and understorey.
Fig. 6.2. Nitrogen concentration in different parts of *Acer laevigatum* in gap and understorey.
Fig. 6.3. Nitrogen concentration in different parts of *Syzygium tetragonum* in gap and understorey.
Fig 6.4. Phosphorus concentration in different parts of *Podocarpus neriifolia* seedlings in gap and understorey.
Fig. 6.5. Phosphorus concentration in different parts of *Acer laevigatum* seedlings in gap and understorey.
Fig. 6.6. Phosphorus concentration in different parts of *Szygium tetragonum* seedlings in gap and understorey.
Fig. 6.7. Potassium concentration in different parts of *Podocarpus neriifolia* seedlings in gap and understorey.
Fig. 6.8. Potassium concentration in different parts of *Acer laevigatum* seedlings in gap and understorey.
Fig. 6.9. Potassium concentration in different parts of *Syzygium tetragonum* seedlings in gap and understorey.
P accumulation was also higher in gap than the forest understorey in all species. P accumulation was more in leaf. Stem and root did not show any significant difference in P accumulation (Fig. 6.11).

K accumulation was significantly higher in gap (P<0.05) as compared to the forest understorey. Variation in K accumulation in different plant parts was noticed only in *Syzygium* where leaf had higher accumulation followed in decreasing order by root and stem (Fig. 6.12).

**Nutrient use efficiency**

The seedlings of all the three species in gap were more efficient in terms of NPK use (Table 6.1).

Table 6.1. Nitrogen, phosphorus and potassium use efficiency (mg dry weight produced /mg nutrient uptake) of *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* in gap and understorey.

<table>
<thead>
<tr>
<th>Nutrient use efficiency</th>
<th>Light conditions</th>
<th><em>Podocarpus neriifolia</em></th>
<th><em>Acer laevigatum</em></th>
<th><em>Syzygium tetragonum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen use efficiency</td>
<td>Gap</td>
<td>171</td>
<td>170</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>Understorey</td>
<td>133</td>
<td>104</td>
<td>136</td>
</tr>
<tr>
<td>Phosphorus use efficiency</td>
<td>Gap</td>
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<td>1655</td>
<td>1293</td>
</tr>
<tr>
<td></td>
<td>Understorey</td>
<td>1487</td>
<td>1332</td>
<td>1033</td>
</tr>
<tr>
<td>Potassium use efficiency</td>
<td>Gap</td>
<td>155</td>
<td>143</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>Understorey</td>
<td>122</td>
<td>124</td>
<td>86</td>
</tr>
</tbody>
</table>

**II. Effect of soil moisture**

**Nutrient concentration in different plant parts**

In all species, N concentration was more in leaf followed by root and stem. The different soil moisture levels had no significant effect on it. In *Podocarpus neriifolia* it ranged from 1.25-1.79% in leaf, 0.40-0.75% in stem and 0.68-1.18% in root. In *Acer*
Fig. 6.10. Nitrogen accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings in gap and understorey.
Fig. 6.11. Phosphorus accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings in gap and understorey.
Fig. 6.12. Potassium accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings in gap and understorey.
laevigatum the respective values were 0.78-2.10, 0.30-0.99% and 0.47-1.21%. In Syzygium
tetragonum concentration in leaf, stem and root were 0.49-1.45, 0.15-0.76% and 0.20-
0.88% respectively. The concentration in different parts decreased significantly (p< 0.05)
from 120 days to 360 days old seedlings (Fig. 6.13, 6.14 and 6.15).

Phosphorus concentration pattern was similar to that of N, with higher value in leaf
followed by stem and root in Acer laevigatum and Syzygium tetragonum. Podocarpus
neriifolia seedlings had high concentration in leaf followed by root and stem. Soil moisture
levels did not have significant effect on P concentration in different plant parts of all
species. It decreased significantly (p< 0.05) after 120 days of seedling growth (Fig. 6.16,
6.17 and 6.18).

Soil moisture levels did not have a significant effect on K concentration in different
plant parts of the seedlings (Fig. 6.19, 6.20 and 6.21).

Nutrient accumulation and allocation pattern in root, stem and leaf

N accumulation was more in leaf followed by root and stem at all soil moisture
levels in all the species (Fig. 6.22). With the increase in age, there was an increase in N
accumulation except in Acer laevigatum in which accumulation in the leaf decreased at
360 days at 30% soil moisture level. There was no definite trend of N accumulation in
Podocarpus neriifolia and Acer laevigatum with the increase in moisture level. However,
in Syzygium tetragonum N accumulation in all parts increased significantly (p< 0.01) with
increase in soil moisture level (Fig. 6.22).

P accumulation in Podocarpus neriifolia and Acer laevigatum did not show
significant variation at different soil moisture levels, but it increased with increasing soil
Fig. 6.13. Nitrogen concentration in different parts of *Podocarpus neriifolia* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.14. Nitrogen concentration in different parts of Acer laevigatum seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC)
Fig. 6.15. Nitrogen concentration in different parts of *Syzygium tetragonum* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.16. Phosphorus concentration in different parts of *Podocarpus neriifolia* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.17. Phosphorus concentration in different parts of *Acer laevigatum* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.18. Phosphorus concentration in different parts of Syzygium tetragonum seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.19. Potassium concentration in different parts of Podocarpus neriifolia seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.20. Potassium concentration in different parts of *Acer laevigatum* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.21. Potassium concentration in different parts of *Syzygium tetragonum* seedlings under three soil moisture levels (A- 20% SMC; B- 30% SMC; C- 40% SMC).
Fig. 6.22. Nitrogen accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three soil moisture levels.
moisture in *Syzygium tetragonum*. P accumulation increased in all plant parts with age, except in *Acer laevigatum* which showed a decrease in the leaf at 360 days (Fig. 6.23).

K accumulation did not vary between different plant parts in all three species. It increased with age in all plant parts, except in *Acer laevigatum* which showed a decrease in the leaf at 360 days. *Syzygium tetragonum* showed marked increase in K accumulation with increasing soil moisture level, whereas in *Podocarpus neriifolia* and *Acer laevigatum* this trend was not observed (Fig. 6.24).

**Nutrient use efficiency**

Nitrogen use efficiency (NUE) increased with increasing soil moisture level in *Podocarpus neriifolia* and *Syzygium tetragonum*. *Acer laevigatum* showed a reverse trend (Table 6.2).

Phosphorus use efficiency (PUE) decreased with increasing moisture level in *Acer laevigatum* and *Syzygium tetragonum* but in *Podocarpus neriifolia* this trend was not observed (Table 6.2).

The Potassium use efficiency (KUE) of the seedlings showed a trend similar to that of NUE (Table 6.2).

Table 6.2. Nitrogen, phosphorus and potassium use efficiency (mg dry weight produced /mg nutrient uptake) of *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* under three soil moisture levels.

<table>
<thead>
<tr>
<th>Nutrient use efficiency</th>
<th>Soil moisture levels (%)</th>
<th>Podocarpus neriifolia</th>
<th>Acer laevigatum</th>
<th>Syzygium tetragonum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen use efficiency</td>
<td>20</td>
<td>93</td>
<td>132</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>98</td>
<td>123</td>
<td>193</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>124</td>
<td>120</td>
<td>206</td>
</tr>
<tr>
<td>Phosphorus use efficiency</td>
<td>20</td>
<td>2178</td>
<td>1492</td>
<td>2163</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1932</td>
<td>1204</td>
<td>2047</td>
</tr>
</tbody>
</table>
Fig. 6.23. Phosphorus accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three soil moisture levels.
Fig. 6.24. Potassium accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three soil moisture levels.
### III. Effect of NPK level in soil

**Nutrient concentration in different plant parts**

N concentration (%) in different species and plant parts did not vary significantly at different soil NPK levels. However, it decreased with age in all cases. Leaf had higher N concentration in all species at all three NPK levels. In *Podocarpus neriifolia* N concentration in root was less than stem during the initial 120 days of growth, but later on concentration in root increased (Fig. 6.25). *Acer laevigatum* did not show any trend (Fig. 6.26). In *Syzygium tetragonum* N concentration in root was more than stem at 120 days, beyond this age no trend was observed (Fig. 6.27).

With increase in the age P concentration (%) in different parts of seedling decreased in all the three species. Leaf had higher concentration in all species at all three NPK levels. *Podocarpus neriifolia* root had higher P concentration than the stem. *Acer laevigatum* and *Syzygium tetragonum* stems had higher concentration (Fig. 6.28, 6.29 and 6.30).

Soil NPK levels has no effect on K concentration in all the species. K concentration was generally higher in the leaf of all species (Fig. 6.31, 6.32 and 6.33).

**Nutrient accumulation and allocation pattern in root, stem and leaf**

Nitrogen accumulation was more in leaf of all the species at all soil NPK levels. All the species accumulated more N in root than stem. With the increase in age of the seedlings there was an increase in N accumulation except in *Acer laevigatum* leaf where it
Fig. 6.25. Nitrogen concentration in different parts of *Podocarpus neriifolia* seedlings under three NPK levels.
Fig. 6.26. Nitrogen concentration in different parts of *Acer laevigatum* seedlings under three NPK levels.
Fig. 6.27. Nitrogen concentration in different parts of *Syzygium tetragonum* seedlings under three NPK levels.
Fig. 6.28. Phosphorus concentration in different parts of *Podoarpus neriifolia* seedlings under three NPK levels.
Fig. 6.29. Phosphorus concentration in different parts of *Acer laevigatum* seedlings under three NPK levels.
Fig. 6.30. Phosphorus concentration in different parts of *Syzygium tetragonum* seedlings under three NPK levels.
Fig. 6.31. Potassium concentration in different parts of *Podocarpus neriifolia* seedlings under three NPK levels.
Fig. 6.32. Potassium concentration in different parts of *Acer laevigatum* seedlings under three NPK levels.
Fig. 6.33. Potassium concentration in different parts of Syzygium tetragonum seedlings under three NPK levels.
decreased at 360 days old seedlings at all soil NPK levels. *Podocarpus neriifolia* registered an increase in N accumulation in leaf and stem with increase in soil NPK levels (Fig. 6.34).

P accumulation in *Syzygium tetragonum* and *Podocarpus neriifolia* was higher in leaf followed by root and stem at all soil NPK levels. There was no significantly difference in P accumulation with the increase in soil NPK levels in different plant parts of all three species. There was a progressive increase in P accumulation in different plant parts with age of the seedlings except in the leaf of *Acer laevigatum* which showed a decrease at 360 days at all soil NPK levels (Fig. 6.35).

K accumulation in *Podocarpus neriifolia* was more in leaf followed by root and stem at all soil NPK levels. In *Acer laevigatum* and *Syzygium tetragonum* no definite trend was observed. There was an increase in K accumulation with age in all parts except in *Acer laevigatum*, which showed a decrease in the leaf at 360 days at all soil NPK levels (Fig. 6.36).

**Nutrient use efficiency**

Nitrogen use efficiency (NUE) increased with increasing soil NPK level in *Podocarpus neriifolia* and *Syzygium tetragonum*. In *Acer laevigatum* the trend was not clear (Table 6.3).

In *Syzygium tetragonum* Phosphorus use efficiency (PUE) decreased with increasing soil NPK levels, but it did not happen in *Acer laevigatum* and *Podocarpus neriifolia* (Table 6.3).
Fig. 6.34. Nitrogen accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three NPK levels.
Fig. 6.35. Phosphorus accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three NPK levels.
Fig. 6.36. Potassium accumulation in *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* seedlings at three NPK levels.
With increase in soil NPK levels Potassium use efficiency (KUE) of *Podocarpus neriifolia* decreased, while *Syzygium tetragonum* and *Acer laevigatum* did not show any definite trend (Table. 6.3).

Table. 6.3. Nitrogen, Phosphorus and Potassium use efficiency (mg dry weight produced /mg nutrient uptake) of *Podocarpus neriifolia*, *Acer laevigatum* and *Syzygium tetragonum* at three soil NPK levels.

<table>
<thead>
<tr>
<th>Nutrient use efficiency</th>
<th>Soil NPK levels (%)</th>
<th><em>Podocarpus neriifolia</em></th>
<th><em>Acer laevigatum</em></th>
<th><em>Syzygium tetragonum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen use efficiency</td>
<td>Half dose</td>
<td>78</td>
<td>139</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>Full dose</td>
<td>71</td>
<td>111</td>
<td>197</td>
</tr>
<tr>
<td></td>
<td>Double dose</td>
<td>63</td>
<td>132</td>
<td>202</td>
</tr>
<tr>
<td>Phosphorus use efficiency</td>
<td>Half dose</td>
<td>1957</td>
<td>1420</td>
<td>1727</td>
</tr>
<tr>
<td></td>
<td>Full dose</td>
<td>1869</td>
<td>1066</td>
<td>1442</td>
</tr>
<tr>
<td></td>
<td>Double dose</td>
<td>2616</td>
<td>1115</td>
<td>1403</td>
</tr>
<tr>
<td>Potassium use efficiency</td>
<td>Half dose</td>
<td>114</td>
<td>120</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>Full dose</td>
<td>103</td>
<td>107</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Double dose</td>
<td>96</td>
<td>114</td>
<td>112</td>
</tr>
</tbody>
</table>

Discussion

In the present study NPK concentration decreased with increase in age of the seedlings of all species. The foliage N concentration in *Acer laevigatum* (0.66 to 3.07), *Podocarpus neriifolia* (0.75 to 2.25) and *Syzygium tetragonum* (0.60 to 1.45) falls within the range (1.49-3.03%) to those reported (2.39-2.65%) by Lodhiyal and Lodhiyal (1997) in *Populus deltoides* and for Poplar plantations (1.49-3.03) raised in different parts of the world (Van Veen et al. 1981; Carlisle and Methven 1997). Hawkins et al. (1999) found that one year seedlings of *Pseudotsuga menziesii* and *Abies amabilis* had higher concentration of nutrients than second year seedlings, indicating that new growth was a stronger sink for nutrients. High N content in leaves as compared to roots and stem confirms the results reported for *Populus ciliata* (Deol and Khosla 1983) and *Acer*
oblongum (Masoodi et al. 1996). Higher allocation of nutrient to different plant parts play significant role in the growth and development of plant species. For example, higher allocation of nutrients to root and stem enables the species to survive in low soil nutrient condition, and a higher allocation of nutrient to leaf has important ecological implications especially in nutrient recycling since leaves constituted the highest proportion of the litter fall in terrestrial communities.

Higher concentration of nitrogen in the leaf during the initial leaf growth has also been reported by Santa Regina et al. (1997), who argued that during spring season, cellular growth is accompanied by high mitotic activity leading to strong demand for nutrients particularly nitrogen. During autumn demand for nutrients decreases due to low cell activity (Ryan and Bormann 1982). The older leaves are known to accumulate much less phosphate than younger leaves, and to export nitrogen, phosphorus and potassium as they age (Leopold and Kriedemann 1980).

Deciduous species have higher concentration of nitrogen, phosphorus and potassium in the leaves than evergreen species (Chapin et al. 1980). In the present study too, concentration of nitrogen, phosphorus and potassium in the deciduous Acer laevigatum was higher than evergreen Podocarpus and Syzygium even at their seedling stage.

Biomass allocation does not reflect qualitative trends in nutrient allocation (Abrahamson and Caswell 1982). However, it is a reasonable currency to measure the nutrient allocation pattern. Studies on nutrient allocation, which could be related directly to
nutrient limitation, is particularly valuable in the assessment of the successful adaptation of a species in the natural ecosystem (Shaver and Chapin 1980).

The nutrient use efficiency (mg dry weight produced/mg nutrient uptake) in the present case is similar to *Populus deltoides* seedlings that ranged between 159 and 175 for Nitrogen, 1405 and 1569 for Phosphorus and 295 and 332 for Potassium (Lodhiyal et al. 1995).

In the present study, there was no trend in nutrient use efficiency with the increase in NPK levels. It appears that the concentration of NPK level in soil was not high enough to cause marked variation in its availability or nutrient requirement of these species was low. Hiremath and Ewel (2002) have reported that nutrient use efficiency of the species is low at high soil fertility. High nutrient use efficiency of the plant species is an adaptive strategy to survive on sites of low soil fertility (Srivastava and Behl 2002). Elliot and White (1994) have suggested that red pine seedlings can adjust their nutrient use efficiency, particularly for N, when light and nutrient availability were limited.

Nutrient use efficiency is also influenced by irradiance. The higher NPK use efficiency in gap in all three studied species suggests that the availability of irradiance rather than major soil nutrients seems to be the limiting factor for the growth of seedlings in this environment. Thus greater nutrient use efficiency in gap appears to be the cause of higher total accumulation in plant body. Increased NUE and PUE in *Euterpa edulies* seedlings with increased irradiance have been reported by Illenseer et al. (2002). High nutrient use efficiency of the plant species could be an adaptive strategy to survive on sites of low soil fertility.