
Effects of N-Fertilization on Instantaneous Carbon Fixation Ability of Douglas-Fir Foliage: Relative Importance of Leaf Area and Photosynthetic Rate

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It is well understood that trees respond to nitrogen fertilization by increasing leaf area and photosynthetic rates. We wanted to investigate how this nitrogen-mediated response might lead to increases in productivity. Physiological interactions occur between light environment, leaf area, leaf nitrogen and photosynthetic capacity and we have done research to explore these interactions in the context of productivity. The objective of our research was to examine the relative contribution of increased leaf area and increased photosynthetic rates on leaf carbon balance caused by nitrogen fertilization in different canopy positions and among different leaf age classes. In the top part of the tree crowns, light is not a limiting factor. The amount of nitrogen available to the leaves is a decisive factor in photosynthesis. On the other hand, at the bottom of the canopy, because more nitrogen is allocated to the higher light environments, both light and nitrogen are limiting. So increasing the amount of nitrogen may or may not increase the photosynthetic capacity of leaves depending on which factor is more limiting. Furthermore, fertilization tends to shift the leaf area toward upper canopy so as to increase the mutual shading in the lower canopy. However if the foliage in the lower crown is more nitrogen limited, then increasing nitrogen to these leaves will increase the photosynthetic capacity and partly counterbalance the negative effect of mutual shading. We are expecting that the amount of carbon production through nitrogen fertilization contributed by increased photosynthetic rates would increase from top to bottom of the crown.

BACKGROUND

A 15-year-old Douglas-fir plantation in Snoqualmie Tree Farm was chosen as the study site. The stand was planted in 1985 with 2-0 seedlings after a clear-cut on a 40% slope. Measured in the March of 1997, average tree heights were 11.6 and 11.0 m and DBHs', were 13.7 and 15.7 cm in unfertilized and fertilized plots, respectively. One stand was fertilized in March of 1993 and again in 1997 with 224 kg N / ha of urea, the other served as a control. Two trees from each plot were selected for leaf area measurements by using a systematic branch sampling technique. A model was constructed to predict leaf area from branch diameter and its relative position within a tree's crown for each treatment. To calibrate the equations, one big tree in each plot with similar DBH was selected and a modified stratified-clip sampling technique was used to calibrate the model developed by the systematic sampling method. Light saturated photosynthesis was also measured in April of 1998 using a Li-Cor 6200 on several different age classes of foliage from the 3rd, 5th and 7th whorl which corresponded to the upper, middle, and lower crown positions. A branch's instantaneous carbon fixation ability was calculated as the sum of the products of light saturated photosynthetic rate and leaf area for each age class of foliage on a branch. Then increased carbon fixation production through N fertilization was partitioned into two parts: carbon production due to increased photosynthetic rate and carbon production due to increased foliage area.

RESULTS

The results showed that N fertilization increased leaf area and net photosynthesis over all canopy positions. Compared to the control, fertilized trees have 120%, 92%, and 100% more leaf area for a given nodal branch in upper, middle, and lower crown positions respectively (Figure 1).

Figure 1. Comparison of leaf area of typical branches in different crown positions between

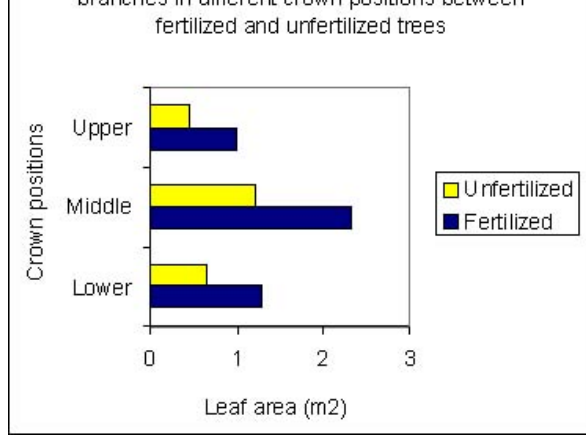


Figure 1

Light saturated photosynthetic rates of fertilized trees were also 29%, 97%, and 96% higher than the corresponding branches of unfertilized trees (Figure 2).

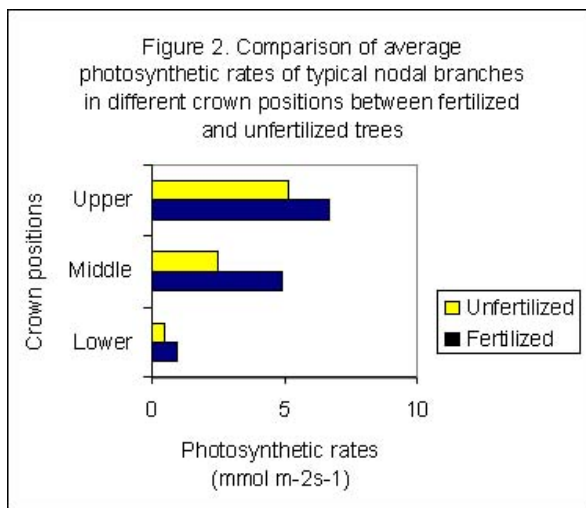


Figure 2

In the upper crown position, 85% of the increased carbon production of foliage by N fertilization was through increased leaf area, while in the middle and lower crown positions, it was 65% and 68% respectively (Figure 3).

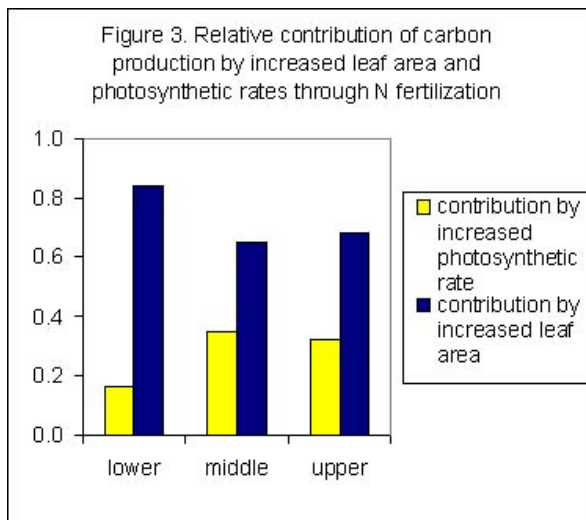


Figure 3

The ssremainder was through increased rates of net photosynthesis. In terms of current year foliage, more

than 90% of the increased carbon fixation ability was contributed by increased leaf area and less than 10% was contributed by increased photosynthetic rates and the relative contribution of increased photosynthetic rates increased as one goes from top to the bottom of the crown (Figure 4).

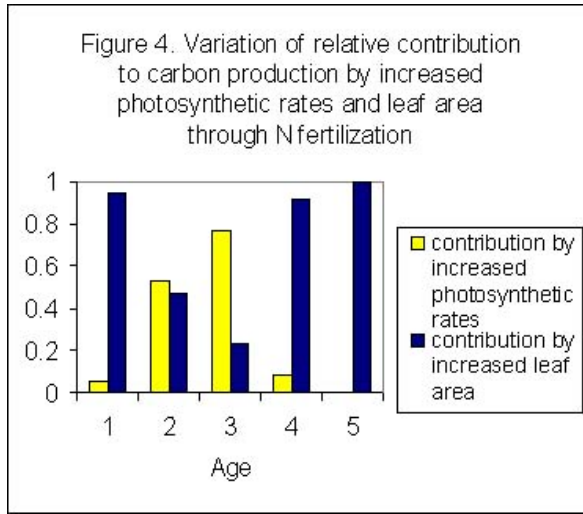


Figure 4

Also it appears that the amount of contribution by increased photosynthetic rates increased from one-year old needles until 3-year-old needles, then declined for needles in the upper and middle crown positions. There was no apparent pattern over age for the needles in lower crown positions.

CONCLUSION

We found that fertilized Douglas-fir trees have much more leaf area than unfertilized trees. Light-saturated rates of photosynthesis increased in fertilized trees, and this did not have much of a pattern with leaf age. We feel that the larger productivity of the fertilized trees is mostly due to their increased leaf area, and secondarily due to their increased photosynthesis. There is a strong interaction of light and nitrogen. Big trees benefit most from fertilization.