# LEAF AREA AND GIRTH RELATIONSHIP IN *POPULUS DELTOIDES* GROWN IN NWFP, PAKISTAN

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## Abstract

In order to determine the relationship between leaf area and girth of *P.deltoides* trees grown in Charsadda district of NWFP area, simple, multiple and double log regression analysis was carried out. Girth of the tree was used as dependent variable and leaf area, age and space were used as independent variables. In this regard, data were collected from 2 and 7 years old compact plantations, 3 years intercropping plantation and 8 years linear plantations. It was found that simple regression equations showed better predictability in terms of F-value and R-square estimates. The highest correlation between girth and leaf area was estimated at the age of two years because of higher photosynthetic activity due to large leaf surface area, while the lowest relationship between girth and leaf area was found at the age of 8 years because of maturity of the tree crops. Leaf area/girth ratio decreased from 2 years to 8 years. Leaf area, age and spacing explained about 84.5 percent of total variation in the girth of the trees.

## Introduction

Poplars are widely distributed in areas with cooler climate in the Northern hemisphere. The natural Poplar forests exist in Canada and USA. The introduction of exotic poplar in Pakistan started in late fifties. The first introduction was from USA, Yugoslavia, Turkey, Netherlands, Australia, etc. Over a period of time, scientific production of nursery stock and field planting techniques have been streamlined. A number of studies were laid out to find out the best spacing and comparison of different poplar clones at a number of places under intensive methods of agro-forestry. Suitability of some clones like *Populus euramericana* CV – I –214 , and *Populus deltoides* 63 /51 , 81 /62 , 90/ 60 , 69/55 etc, have been indicated for large scale planting ( Sheikh , 1985 ).

Poplar is emerging as the premier short rotation plantation timber for industrial use. In Pakistan, the match industry is the major user of poplar wood grown on farmlands and more than 50 % of match factories are totally dependent on poplar wood for raw material (Sheikh, 1985). Poplar wood is also

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frequently used for packing, shuttering, veneer, furniture, sports goods, chipboard industry, pulp and paper industry and matches due to its white colour, good workability, softness, light weight, relatively high strength in proportion to weight and resistance to splintering. Leaves, branches and even small size inferior logs are quite commonly used for cooking and heating. Poplar logs are also exported to Afghanistan where it is used extensively in the ordinary house construction. It is expected that derived demand for poplar wood will further increase in near future because of increased use of forest products in the country as a result of population growth and rehabilitation process in the Afghanistan.

In order to further promote the utility of poplar wood in the forest-based industry, it is important to develop better management strategies to increase the per hectare productivity, improve the quality of logs and create the maximum value of the logs grown under different agro-forestry systems. An indirect measure of the productivity is the growth rate of trees.

To predict the growth of the poplar trees grown on farmlands, a study was conducted using the tree level as well as stand level variables. The study was carried out in district Charsaddah, which is famous for growing poplar trees on farmlands. Here the poplar trees are grown in various types of plantations i.e. linear, block and intercropping etc.

**Review of Literature**

Growth of tree depends upon a number of factors like, soil conditions, climatic conditions, management regimes and species. All the favorable growing conditions result into an increase in the leaf area of the trees. Leaf area is one of the indices of the growth rate and future productivity of the tree crops. As the leaf area increases, rate of photosynthesis also increases and ultimately it results into an increase in the growth rate and per hectare productivity of tree crops under different management systems (Taiz et.al, 1998). Generally, the stand-level models are used to predict the growth of the stand. Recent improvements in high-speed computing equipment have made it possible for growth modelers to use the individual tree rather than the stand as the basic prediction unit. The basic distinction between the two type is that the predictor variables in stand-level model are stand statistics, while at least some of predictor variables in any tree-level models are individual tree statistics (Clutter. et. al , 1983).

Raulier et.al (1997) described a functional relationship between leaf

area, fractal dimension of the crown surface, shade tolerance and light availability. This relationship is obtained by setting an arbitrary limit between crown porosity to light and crown convolution. A crown profile is modeled from the total length and horizontal extension of second-order branches to estimate the crown surface area. A submodel simulates total canopy openness from geometrical characteristics of the crown of first-order neighbors to estimate light availability. To allow its insertion into growth and yield models, the model was simplified and validated with data gathered in 6 stands dominated by sugar maple (*Acer saccharum)*, in southern Quebec.

Burman and Sharma (1995) used five types of regression equations (linear, simple exponential, power, exponential and logarithmic linear) were developed to establish the relationship between leaf area and corresponding leaf dry weight in *Prosopis juliflora* seedlings. Of these, the power curve numerically expressed the best possible relationship between these 2 parameters, and the equation developed at the 3-month stage had sufficient predictability as evidenced by the t-test of significance.

Penner and Deblondes (1996) estimated relationships between leaf area and sapwood area, sapwood area and basal area, and leaf area and basal area growth for jack pine (*Pinus banksiana)* and red pine (*P. resinosa*) in the Petawawa Research Forest, Ontario, Canada. Relationships varied with species and stand origin. Growth efficiency (basal area growth per unit leaf area) was relatively independent of tree size.

Iqbal et.al (1992) studied Lombardy poplar (*P. nigra, Italica Muench*) grows in Pakistan to develop simple and practical prediction models using linear regression to estimate crown biomass. Models were developed for green and air dried branch wood and fodder crown biomass components under different lopping intensities. Diameter at breast height squared and its square proved to be the best independent variables to predict the crown biomass weights.

## Material and Methods

In Charsadda district people grow poplar in different patterns, but most of them grow poplars along the water channels and on the boundaries of the agriculture fields, while some of them do block plantation. Sample plots from compact plantation, intercropping and linear plantation were selected to represent different patterns of agro-forestry in Charsadda district. Compact plantation are those plantations in which plants are raised at particular spacing, in the form of groups, while intercropping is also a compact plantation but

agricultural crops are also cultivated in between the lines of trees. In linear plantations trees are planted in one or more rows at specific tree to tree distance along the water channels, roads and boundaries of the agricultural fields for multiple benefits.

***A compact plantation of Poplars***

Table 1. Sample plots from different types of Poplar plantations in Charsadda district

| *S. No* | Type of plantation | *AREA ($m^2$)* | *SPACING (m)* | *AGE* (year) | *Name of Place.* |
|---|---|---|---|---|---|
| 1 | Compact Plantation | 506 | 1.8 x1.8 | 2 | Tooty Pul |
| 2 | Inter cropping | 1012 | 6.1 x 0.6 | 3 | Sheikh Killay |
| 3 | Compact Plantation | 506 | 1.8 x 1.8 | 7 | Sheikh Killay |
| 4 | Linear Plantation | Length 91m | 0.9 x 0.9 | 8 | Gullbelah Charsadda road. |

Table 1 shows the location, type of plantations and spacing of sampled plots selected for the study. For primary data collection, on average 25 trees

were selected randomly from each plot. Girth of each tree was measured at breast height. 10 – 15 leaves were collected from each tree randomly. Age of the plantation was obtained from the owner of the sample plots.

In order to measure the leaf area the technique which was proposed by Ahmed and Rukhsana (2001) was modified accordingly. The paper sheets, were weighed and image of fresh leaves were drawn on the paper sheets. T the images drawn on paper sheet were cut and weighed. The following formula was used to determine the leaf area.

| | | |
|---|---|---|
| LA | = | S.A / Wt.S X wt.S.L |
| LA | = | Leaf Area |
| S. A | = | Sheet Area |
| Wt.S | = | Weight of Sheet |
| Wt. S. L | = | Weight of Sheet Leaf |

For data analysis, simple regression, logarithmic linear regression and multiple regression techniques were used to estimate the relationship between growth rate, leaf area , age and spacing. To estimate the quantative relationship, girth was used as dependent variable, while leaf area, age and spacing were used as independent variables to estimate the quantitative relationship. Minitab computer programme was used for regression analysis.

## Results and Discussion

### Descriptive statistics

Descriptive statistics of the study is shown in Table.2. From the results it appears that mean leaf area of 2,3,7,and 8 years old poplar plantation is 77.5 ,47.3, 83.6 and 96.6 $Cm^2$ respectively. Generally, the leaf area increased with girth of the tree from age 2 to 8 years except for the poplar trees grown in agroforestry system. Poplar trees grown with the agriculture crop were planted from East to West and at a very close spacing (0.61m). Perhaps all the trees grown under such orientation and close spacing were not receiving equal sunlight for their growth.

Table 2. Descriptive Statistics of leaf area and girth of Poplar trees

| Plantation Type | Variable | Age (Year) | Obs. | Mean | Median | Std Dev |
|---|---|---|---|---|---|---|
| Compact | L.Area ($Cm^2$) | 2 | 270 | 77.52 | 65.86 | 39.93 |
| Compact | Girth (Cm) | 2 | 270 | 13.70 | 13.00 | 3.44 |
| Intercropping | L.Area ($Cm^2$) | 3 | 340 | 47.35 | 42.54 | 25.47 |
| Intercropping | Girth (Cm) | 3 | 340 | 27.662 | 28.00 | 6.62 |
| Compact | L.Area ($Cm^2$) | 7 | 280 | 83.56 | 75.00 | 39.30 |
| Compact | Girth (Cm) | 7 | 280 | 56.00 | 53.00 | 10.49 |
| Linear | L.Area ($Cm^2$) | 8 | 230 | 96.64 | 91.18 | 34.10 |
| Linear | Girth (Cm) | 8 | 230 | 65.04 | 63.0 | 14.40 |

Similarly, the girth of trees increased with the age. Girth of the trees at the age of 2 years was 13.7 centimeters, it increased to 65.0 centimeters at the age of 8 years under different management schemes.

**Leaf area / girth ratio**

Table 3 discusses the leaf area/girth ratio of poplar trees at different ages. The highest leaf area/girth ratio was recorded at the age of 2 years (5. 7) for compact plantation and the lowest at the age of 8 years for linear plantation (Fig 1). There was not significant difference in LA/GI ratio at the age of 7 and 8 years. These results are quite in accordance with the expectations. At younger age, rate of height growth of poplar trees was higher than growth in girth, which subsequently decreased at the age of 8 years. After attaining certain height with a rapid initial height growth, generally trees start taking more growth in diameter. The highest LA/GI ratio at the age of two years indicates higher photosynthesis activity (Keith, 1998) compared to the other age groups studied in this study. Similar relationship was reported by Douglas (1995), who found an inverse relationship between leaf area and age class of seedlings of *Salix setchelliana*.

Table 3. Leaf area/girth ratio of poplar trees at different ages.

| Age (years) | Mean Leaf area ($Cm^2$) | Mean Girth (Cm) | Leaf area / Girth ratio |
|---|---|---|---|
| 2 | 77.5 | 13.7 | 5.7 |
| 3 | 47.3 | 27.7 | 1.7 |
| 7 | 83.5 | 56.0 | 1.5 |
| 8 | 96.6 | 65.0 | 1.5 |

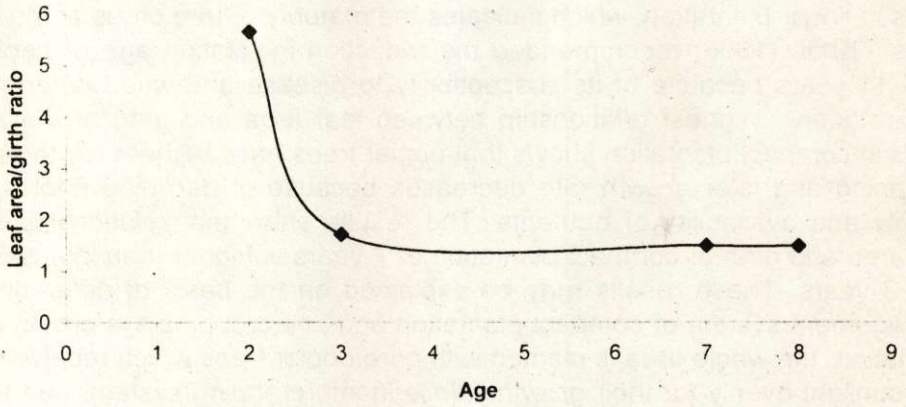


**Fig. 1 Relationship between age and leaf area/ girth ratio of P.deltoides trees**

## Simple Regression Model

Table 4 shows the simple regression equations for poplar plantations of different age groups (Fig 2, 3 and 4) and spacing. A unit increase in leaf area will result into 3.4 percent increase in the girth of the tree at the age of two years. Similarly, a unit increase in the leaf area will increase the girth of the tree by 3.1 percent at the age of 3 years under intercropping management system.

A unit increase in the leaf area of poplar trees at the age of 7 years will result into an increase in the girth of the poplar trees by 3.6 percent for compact plantation. It appears that at different age groups, intercept changes but with a nominal difference in the slope. Similar results were reported by

Brenner et al. (1991), who determined the relationship between stem basal area of young neem tree and leaf area.

Table 4. Relationship between leaf area and girth (Simple regression)

| *Age (Years)* | *Plantation Type* | *Spacing (m)* | *Simple Linear Regression Equations* |
|---|---|---|---|
| 2 | Compact | 1.8 x1.8 | GI=11+0.0342LA R-SQ=15.8% F=50.31 p=0.000 |
| 3 | Intercropping | 6.1 x 0.6 | GI=26.2+0.0312LA R-SQ=1.4 % F= 4.93 p=0.027 |
| 7 | Compact | 1.8 x1.8 | GI=53.0+0.0362LA R-SQ=1.8 % F= 5.20 p=0.023 |
| 8 | Linear | 0.9 | GI=62.8+0.0222LA R-SQ=0.3 % F= 0.63 p=0.429 |

Relationship between leaf area and girth is not significant at the age of 8 years in linear plantation, which indicates the maturity of tree crops at the age of 8 years. Khan (1996) recommended the reduction in rotation age of poplar trees from 11 years because of its susceptibility to disease and wood deterioration in long rotation. Highest relationship between leaf area and girth at the age of 2 years in compact plantation shows that poplar trees have higher growth rate in the beginning and later growth rate decreases because of declining photosynthesis activity and availability of nutrients. The results show that relationship between leaf area and girth of compact plantation of 7 years is higher than intercropping at age 3 years. These results may be explained on the basis of difference in the management system of compact plantation and intercropping system. In compact plantation, the whole area is planted with pure poplar trees which receive nutrients and sunlight evenly for their growth. While in intercropping system, due to East – West orientation of trees, close spacing and presence of agricultural crops, trees are not receiving the required nutrients and sunlight at the age of 3 years, whereas growth of poplar tree is highly influenced by the availability of sunlight (Jennifer, 1999). Here it may be inferred that growth rate of poplar trees in the beginning is not always higher, rather management system determines the growth rate of poplar trees.

**Logarithmic Linear Models**

Table 5 shows the double log regression equation (logarithmic linear model) indicating the relationship between girth and leaf area. If simple regression models is compared with double log regression models, it appears that simple regression equations numerically express the best possible relationship between girth and leaf area and have sufficient predictability in terms of F-value and R-square. In both models, simple regression and logarithmic linear modes, linear plantation has the least relationship between girth and leaf

area at the age of 8 years. Simple regression model and double log model both show significant relationship between leaf area and girth in compact plantations as well as for intercropping mode of plantation.

Table 5. Double log regression equations showing the relationship between girth and leaf area.

| Age (Year) | Spacing (m) | Double Log Regression Equations (Logarithmic Linear) |
|---|---|---|
| 2 | 1.8 x1.8 (compact) | lnGI=1.93+0.158lnLA R-SQ=14.00 % F=44.32 p=0.000 |
| 3 | 6.1 x 0.6 ( intercrop) | lnGI=3.07+0.0594lnLA R-SQ=1.1 % F=3.72 p=0.050 |
| 7 | 1.8 x1.8 (Compact) | lnGI=3.95+0.0000659lnLA R-SQ=2.0% F=5.56 p=0.023 |
| 8 | 0.9 x 0.9 (Linear) | lnGI=3.99+0.0354lnLA R-SQ=0.3 % F=0.74 p=0.391 |

## Multiple Regression Models

Table 6. shows the results of multiple regression ( mixed age groups 2, 3,7 years and 2 and 7 years) based on three independent variables, i.e. leaf area, age and spacing. These results of the multiple regression indicate a significant relationship between independent variables i.e. leaf area, age and spacing and dependent variable girth of the trees. When regression model included only two age groups of compact plantations and excluded the inter-cropping 3 year plantation data and spacing data from the analysis, R –square value increased to 88.3 percent from 84.5 percent. F–value also increased from 1613.03 to 2057.39, which indicates the strong relationship between girth of poplar trees with leaf area and age when planted in compact form.

Table 6. Multiple regression equations of *P: deltoides* plantations models.

| Age ( years) | Multiple Regression Equations |
|---|---|
| 2, 3,7 | Girth = -65.0+0.0344LA+8.42 AG+1.64 SP<br>S=7.319 R-square=84.5% F=1613.03 p=0.000 |
| 2,7 | Girth = -5.86+0.0352 LA +8.42 AG<br>S=7.47 R-Square = 88.3 % F=2057.39 p=0.000 |

(Independent variables LA = leaf area, AG = age, SP = spacing)

## Conclusions

Results of the study confirm a positive relationship between leaf area and girth of Poplar trees. However, relationship between the two parameters varies

with age and spacing of the tree crops. It was observed that at different ages, intercept varies with the age group but change in coefficient of leaf area is nominal in the regression equation.

Highest correlation between girth and leaf area was found at the age of 2 years. The lowest correlation between leaf area and girth indicates the maturity of the crop at the age of 8 years in linear plantation. Leaf area/girth ratio was highest at the age of 2 years and it decreased with age. The lowest LA/GI ratio was observed at the age of 8 years. Linear regression equations are better predictors of leaf area and girth relationship as compared to the double log equations. Present study also reveals that at the age of 3 years, the relationship between leaf area and girth must be higher but due to planting pattern, and close spacing poplar trees were not receiving enough sunlight for normal growth. These findings are further supported by the lower R-SQ values (Table 4) intercropping planting type. Leaf area, age and spacing account for 84.5 % variation in the girth of poplar trees.

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