GROWTH POTENTIAL AND THINNING YIELD STUDIES OF UTTAR PRADESH CHIR PINE

BY

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It is well known that in nature, the stocking of young under stocked stand increases in an effort to attain normal growing condition, while an overstocked stand exhibit a decreasing trend. There is always a optimum level of stocking for particular time and site quality to enable stand to put on the best and ultimately result in maximum total volume production per unit area at a rotation age. Subject to various contraints exercised by market and demand, on suitability of raw material, the forests should follow the optimum level of stocking to avoid losses attributable to management practices.

To evaluate the influence of density of stocking on growth is simple in case of short rotation plantation crops with no intermediate removal of produce by way of thinnings (e.g. *Casuarina equisetifolia* grown for fuel-wood and *Eucalyptus* for paper pulp in India), but in thinned crops, intensity and interval of thinnings make study complicated.

This paper presents the results of study undertaken on *Pinus roxburghii* (Chir) high forest stands. *Pinus roxburghii* occurs gregariously as principal spp. of sub-tropical pine forests in nature with sprinkling of broad leaved associates like *Quercus leucotrichophora*, *Rhododendron arboreum*, *Lyonia ovalifolia*, etc. It is mainly found in Siwalik hills and western Himalayas between 900 m to 1800 m. Stocking of pine forests is variable. Undergrowth of herbaceous plants is scanty though grasses may be found in most of the places.

Pine forests are managed under Uniform system Regeneration period is kept between 20 to 30 years and rotation varies between 90 to 120 years. *Pinus roxburghii* is considerably resistant species, it adopts to drought and intense heat and is frost and fire hardy. However, it is observed that there is a fall in growth as we move towards it Eastern limit of occurrence. Thus to avoid variations on account of geographic distribution, the study has been confirmed to State of Uttar Pradesh which occupies the Eastern most region.

Data has been taken from permanent sample plots. The division-wise distribution of these plots are given below :—

Name of Division	No. of measurements							No. of sample plots	Total No. of observations
	1	2	3	4	5	6	7		
West Almora	—	6	8	6	7	2	1	30	114
Chakrata	—	1	2	2	3			8	31
Nainital	—	2	2					4	10
Dehra Dun						1		1	6
Total	—	9	12	8	10	3	1	43	161

Records of thinnings are available from the time of formation of sample plots only, how much removal occurred before laying out of the sample plot is not known. Further, unlike thinning experiments these sample plots have not been kept at different level of stocking during entire period of observation. Stocking per cent has fluctuated between $\pm$ 15 % of ordinary C grade of thinning volume.

Various symbols used in the text are :—

	Units
v = initial volume at the beginning of growth period.	m^3/ha.
V = Volume at the end of growth period.	m^3/ha.
n = growth period.	Year
r = rate of growth per cent.	%
H = Top height.	metre
T = Top age.	Year
S = Site index at reference age = 60 years.	—
VE = estimated volume at the end of growth period.	m^3/ha
VR = Volume ratio.	—

The approach consists of

(i) Classifying forest area into various productivity site H = f (S,T)

(ii) Estimating volume production under various site class VE = f (S, T)

(iii) Calculating a new independent variable termed as "Volume ratio"

$$VR = \frac{V}{VE}$$

(iv) Utilising "volume ratio" to evolve a function to predict rate of growth per cent.

$$r = f\,(VR, T, \ldots\ldots\ldots)$$

where $\left(1 + \frac{nr}{100}\right) = \frac{V}{v}$

(v) Then for different stages of development optimum "volume ratio" is determined which yield highest value of rate of growth per cent.

VR is optimum when $\frac{dr}{d(VR)} = O$; $\frac{d^2r}{d(VR)^2}$ = Nagative.

(vi) Optimum v is calculated to help the formulation of the aimed cumulative volume growth curve.

Data was classified into various productivity sites with the help of site quality curves deduced by graphic method in preparation of yield and stand tables for chir by Seth, Dabral and Lala. This was done so to provide a common base to compare the results with existing normal yield tables. Following regressions were then developed. Data was in F.P.S.

system and analysed as such but results and regressions are given after conversion into metric system.

Estimated volume/ha

$$\log\left(\frac{VE}{6.99562}\right) = 1.84265 \log(.32809\ H) + \frac{1.33508}{\log(T+10)} - .000138\ S^{2} - .67683$$

$R^2 = .887$

$F = 254.82$

Rate of growth per cent

$$\text{Log}\,(1000\,r + 20.0) = -\,.72635 \log(T) - .00849\,n + .17091 \log(.32809\ H) \times VR + 2.95066$$

$R^2 = .749$

$F = 88.32$

The amount of explained variation is low. It could happen when data pertain to high forest even aged stands as against plantation crop and also on account of mensurational errors in determination of volume increment.

High forests even aged crops possess inherent variability on account of age variation and difficulty in assessment of top age, so precision obtained is much less as compared to plantation crop thinned and managed under similar conditions.

Estimation of accurate volume increment is not easy especially when stand volume is high. The smaller the increment as compared to stand volume, the higher will be the error in estimation.

Apart from these, flunctuations in yearly climatic factors which in turn influence growth introduce variations which are difficult to explain with limited parameters.

Kullervo Kuusela (1964) calculated rate of growth per cent using following regression :—

$$100 \log 1000 \left[(1+\frac{r}{100})^{n/2} - 1 \right] \text{ or } 100 \log (r) = a - b\ 100 \log T - c\,(v+V)/2$$

where a, b and c are constants.

It yielded $R^2 = .815$ for Southern and $R^2 = .461$ for Northern Finland pine areas. In the present attempt there is little difference that in place of stand volume, "volume ratio" has been used to yield better precision. Stand volume was not found to contribute in improving the result.

In data under study the 'volume ratio' does not vary widely.

Mean	1.00984
Standard deviation	.13732

Thus it would be safe to study growth behaviour for volume ratio limits between 0.85 to 1 15, which are within the data range. The regression on rate of growth per cent reveals no maxima when differentiated with respect to 'volume ratio' which indicates that congestion in crops resulting in loss of growth occurs at much higher volume Rate of growth per cent is superior at 1.15 limit when compared to .85 volume ratio, it could probably be on account of higher stem form factor in denser crops. Secondly, as regeneration period of Chir areas is 20 to 30 years, therefore, in all areas this age variation exists. Denser crops have more trees in understorey which are from younger age group and have higher rate of growth per cent. This may attribute to overall increase in growth per cent of denser crops which though is very slight.

No congestion has set in, also gets support from the study of crop diameter. Volume ratio, though used as independent variable has no influence no crop diameter.

$$\text{Log}\left(\frac{D}{2.53998}\right) = 1.72161 \log (.32809 H) - \frac{3.42460}{\log (T+10)} + \frac{14\,21376}{T}$$
$$- .03881 (.32809 H) + 1.42747$$

Where D=crop diameter in cm.

$R^2 = .946$

$F = 424.17$

It is mentioned that if sample plots were kept at different level of stocking during entire period of observation, probably crop diameter would have been influenced a little.

Tables showing crop diameter—Top height relationship and growth and thinning yields of chirpine under different volume ratios are annexed.

A perusal of these tabular statements indicate that chirpine may be grown more densely than it is found to occur generally, to get high volume returns. Level of stocking at "volume ratio" 1.15 or even higher could be adopted. This stocking does not appear to be high *Cedrus deodara* and *Pinus excelsa* which grow at a little higher altitudes in same zone hold much more volume per hectare at the same age.

Pinus excelsa

Age (Yrs)	Site quality	Standing volume/ha (m^3)	M. A. I. (m^3)
100	I	1111.6	15.89
	II	901.0	12.48
	III	670.2	9.22
		Cedrus deodara	
100	I	1005 3	13.84
	II	763.9	10 33
	III	519 8	7.10

Then why not we expect from chir the same. It is felt that accessibility and consequently greater biotic interference in chir zone may be causitive factors for its poor density and hence the low yield.

Managing forests at "volume ratio" 1.00 or at lower level which is mostly the case, the loss in production is at least 20%, implying that soil potential is not fully tapped. The loss is huge and warrant serious consideration. To know which areas require thinnings, is simple. Standing crop volume can easily be assessed by point sampling technique and use of 'stand volume tables'. Estimated volume is then compared with tabulated standing volume for that quality and specified age. If estimated volume is more, then thinnings are needed and difference between these two will give volume to be removed. But it is difficult to implement removal of a certain stipulated volume from an area as compared to thinning out a fixed number or proportion of standing trees. The following regression, is therefore developed to give number of trees per hectare required to be thinned.

Number thinned/total number of trees

$$= \left[1 - \log\left(10.0 \times \left(1 - \frac{\text{Volume thinned}}{\text{Total volume}}\right)\right)\right] \times \log(T)$$

$$\left[3.05502 - 1.52244 \log (39370\ D)\right] + .04885$$

$R^2 = .844$

$F = 266.06$

Regulating thinnings as stated above, in all areas which are not under regeneration felling, will built up growing stock to pay high dividends.

Table 1

Top-height and Crop-diameter relationship

(by site quality and age)

Age	Site quality I		Site quality II		Site quality III	
	Top height (m)	Crop diameter (cm)	Top height (m)	Crop diameter (cm)	Top height (m)	Crop diameter (cm)
20	11.6	11.9	9.1	8.5	6.4	5.0
30	18.0	18.5	14.0	13.5	10.7	9.3
40	23.5	25.1	18.9	19.7	14.3	14.0
50	28.0	31.1	22.9	25.5	17.7	19.0
60	31.7	36.3	25.9	30.4	20.4	23.7
70	34.4	40.8	28.7	35.2	22.6	27.9
80	36.6	44.6	30.5	39.0	24.4	31.8
90	38.1	48.0	32.0	42.5	25.9	35.3
100	39.6	51.3	33.2	45.7	27.1	38.5
110	40.5	54.1	34.1	48.5	28.0	41.4
120	41.5	56.8	35.1	51.3	29.0	44 2

Table 2.1

Growth and yield estimates by age under

Site Quality III
Volume ratio 0 85

(i) Various site qualities
(ii) Level of stocking

(Stem volume/ha)

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)
20	48.6	—	—	48 6	2 43	7.28
30	81.0	—	—	81.0	2.70	5 45
40	116.4	—	—	116 4	2.91	4 31
50	149 1	8.4	8.4	157.5	3.15	3.53
60	176.5	16.5	24 9	201 4	3 36	2.95
70	201.2	19 1	44 0	245.2	3.50	2.49
80	222 6	21.2	65 2	287.8	3 60	2.12
90	240.1	22.9	88 1	328 2	3.65	1.81
100	253 2	24 3	112 4	365 6	3 66	1.56
110	266.7	20.3	132.7	399.4	3.63	1.33

Table 2.2

Site Quality III

Volume ratio 1.00

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)
20	56.3	—	—	56 3	2.82	7 46
30	93.6	—	—	93.6	3 12	5.69
40	134 5	1.8	1.8	136.3	3.41	4 56
50	172.1	13 2	15.0	187.1	3.74	3.78
60	203 7	23 4	38.4	242.1	4 04	3.19
70	232.4	26 8	65.2	297.6	4.25	2.72
80	257.3	29 6	94.8	351 8	4 40	2.34
90	277.6	31 9	126.7	404.3	4.49	2.03
100	292 9	33 6	160 3	453 2	4.53	1.76
110	308 6	29.1	189.4	498.0	4.53	1.53

Table 2.3

Site Quality III

Volume ratio 1.15

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)
20	63.7	—	—	63.7	3.18	7.64
30	105.7	—	—	105.7	3 52	5.94
40	151.7	5.1	5.1	156.8	3 92	4.83
50	194.1	19 0	24.1	218 2	4.36	4.05
60	229.8	31.4	55.5	285.3	4 76	3.45
70	262.2	35 9	91.4	353.6	5.05	2 97
80	290.4	39.5	130.9	421.3	5.27	2.58
90	313.5	42.4	173.3	486 8	5.41	2.26
100	330.9	44 6	217 9	548.8	5.49	1.98
110	348.8	39.5	257 4	606.2	5.51	1.74

Table 3.1

Growth and yield estimates by age under

Site Quality II
Volume ratio 0.85

(i) Various site qualities
(ii) Level of stocking

(Stem volume/ha)

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)[1]
20	72.8	—	—	72.8	3.64	7.77
30	122.3	—	—	122.3	4.08	5.75
40	169.9	8.2	8.2	178.1	4.45	4.57
50	210.4	23.0	31.2	241.6	4.83	3.74
60	249.8	26.3	57.5	307.3	5.12	3.12
70	277.0	38.9	96.4	373.4	5.33	2.65
80	300.2	39.2	135.6	435.8	5.45	2.25
90	318.9	39.3	174.9	493.8	5.49	1.93
100	332.8	39.2	214.1	546.9	5.47	1.66
110	347.1	33.4	247.5	594.6	5.41	1.43

Table 3.2

Site Quality II

Volume ratio 1.00

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)
20	84.0	—	—	84.0	4.20	8.05
30	140.8	—	—	140.8	4.69	6.06
40	195.5	14.1	14.1	209.6	5.24	4.88
50	242.2	32.4	46.5	288.7	5.77	4.04
60	287.7	37.1	83.6	371.3	6.19	3.41
70	319.1	52.5	136.1	455.2	6.50	2.92
80	346.1	53.2	189.3	535.4	6.69	2.51
90	367.9	53.5	242.8	610.7	6.79	2.18
100	384.2	53.4	296.2	680.4	6.80	1.89
110	400.9	46.7	342.9	743.8	6.76	1.65

Table 3.3

Site Quality II

Volume ratio 1.15

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth (%)
20	94.7	—	—	94.7	4.74	8.34
30	158.5	—	—	158.5	5.28	6.38
40	219.8	21.2	21.2	241.0	6.03	5.21
50	272.4	43.4	64.6	337.0	6.74	4.36
60	323.5	50.0	114.6	438.1	7.30	3.71
70	359.1	68.3	182.9	542.0	7.74	3.21
80	389.7	69.5	252.4	642.1	8.03	2.79
90	414.5	70.1	322.5	737.0	8.18	2.44
100	433.2	70.0	392.5	825.7	8.23	2.14
110	452.2	62.6	455.1	907.3	8.25	1.88

Table 4.1

Growth and yield estimates by age under

Site Quality I (i) Various site qualities

Volume ratio 0.85 (ii) Level of stocking

(Stem volume/ha)

Top age (Yrs)	Standing volume (m^3)	Thinnings (m^3)	Accumulated thinning yield (m^3)	Total yield (m^3)	M.A.I. (m^3)	Rate of growth %
20	101.7	—	—	101.7	5.09	8.12
30	161.7	1.5	1.5	163 2	5.44	6.03
40	219 9	19.0	20.5	240.4	6 01	4.78
50	271.4	34.5	55.0	326.4	6.53	3.91
60	312.4	47.8	102.8	415.2	6.92	3.27
70	345.4	53.5	156.3	501.7	7.17	2.77
80	369.2	58.0	214.3	583.5	7 29	2.37
90	393.7	50 6	264.9	658 6	7 32	2 03
100	407.9	55.0	319.9	727.8	7.28	1.76
110	422.3	47.5	367.4	789.7	7.20	1.52

Table 4.2

Site Quality I

Volume ratio 1.00

20	117.0	—	—	117.0	5.85	8.47
30	185 6	6.4	6.4	192.0	6.40	6.41
40	252.4	28 6	35 0	287 4	7.19	5.14
50	311.6	48.3	83.3	394.9	7.90	4.26
60	358.9	64.8	148.1	507.0	8 45	3.60
70	397 2	72.1	220.2	617.4	8.82	3.08
80	424.9	77.7	297 9	722.8	9 04	2 66
90	453.4	69.3	367.2	820 6	9.12	2.30
100	470.0	74.6	441.8	911.8	9.12	2 01
110	486.9	65.8	507.6	994.5	9.04	1.76

Table 4.3

Site Quality I

Volume ratio 1.15

20	131.4	—	—	131.4	6.57	8.83
30	208.2	12.6	12.6	220.8	7.36	6.80
40	283 0	40.2	52.8	323.2	8.08	5.52
50	349.5	64.4	117.2	466.7	9.33	4.62
60	402.7	84.6	201.8	604 5	10.08	3 94
70	445.9	93 8	295 6	741.5	10.59	3.40
80	477.4	100.6	396.2	873.6	10.92	2.96
90	509.8	91.3	487.5	997.3	11.08	2.59
100	528 9	97.4	584.9	1113.8	11.14	2.29
110	548.3	87.3	672.2	1220.5	11.09	2 02

SUMMARY

The paper presents a mathematical approach to the preparation of yield tables for different density stands which are subjected to thinnings at various stages of development. Chirpine data of Uttar Pradesh have been utilised to develop various relationships. It is felt that stocking of chirpine is low in natural forests and production per unit area could be much enhanced by judicious implementation of thinnings.

उत्तर प्रदेश में सामान्य चीड़ की वृद्धि क्षमता तथा उसके विरलन से प्राप्ति सम्बन्धी अध्ययन

लेखक एस० पी० सिंह

सारांश

इस अभिपत्र में विभिन्न घनत्वों वाले खड़े वनों की, जिनमें वन विकास के विभिन्न चरणों में विरलन कराया जाता है, प्राप्ति सारणियां बनाने के लिए गणितीय दृष्टि को प्रस्तुत किया गया है। उत्तर प्रदेश के सामान्य चीड़ के आंकड़ों का उपयोग उनके कई तरह के सम्बन्ध स्थिर करने के लिए किया गया है। अनुभव किया गया है कि सामान्य चीड़ के प्राकृतिक वनों में वृक्ष घनत्व कम है और विरलनों को सूझ-बूझ द्वारा क्रियान्वित कराने पर क्षेत्र की प्रति इकाई के विचार से उत्पादन काफी बढ़ाया जा सकता है।

Wachstumes Potential und Durchforstungertragstudien der UP Chirkiefer

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ZUSAMMENFASSUNG

Der Artikel schenkt eine mathematische Annäherung nach der Bildung die Ertragtabellen für verschiedenen dichtigkeiten Bestanden, die an verschieden Bühnen der Entwicklung zur Durchforstung untergeworfen sind. Die Chirkieferangaben des Uttarpradeshs sind verschiedenen Verwandtschaften zu entwickeln, benutzt. Das ist gefühlt daß die Bestockung der Chirkiefer in natürlichen Försten niedrig ist, und ihre Produktion pro Einheit der Flächen, bei verständiger Ausführung der Durchforstungen mehr vergrößern kanne.

Etudes relatives aux potentiel d'accroissement et des produits d'éclaircie sur le "Chir Pine" de l'Uttar Pradesh.

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Résumé

Cet article présente une approche mathématique qu'on peut utiliser pour la construction des tables de rendement pour différentes densités des peuplements, coumis à l'éclaircie à divers moments de leur développement. On y a utilisé les données fournies par les peuplements de "Chir Pine" créés dans l'Etat de l'Uttar Pradesh. On a constaté que le degré de densité de "Chir Pine" est peu élevé dans les foréts vierges et qu'il est possible de rehausser la production par l'unité de l'aire en pratiquant judicieusement l'éclaircie.

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