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Optimising Anatolian Black Pine (*Pinus nigra*) and Turkish Red Pine (*Pinus brutia*) seedling production in state forest nurseries of Turkey

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Abstract

Aim of study: In this study, Anatolian black pine (*Pinus nigra*) and Turkish red pine (*Pinus brutia*) seedling production at different ages were planned with linear programming method and maximizing the seedling revenues was aimed.

Material and Methods: In this respect, according to the assumptions used in the model, fields in various sizes such as 10000 m^2 area for one year old, 20000 m^2 for two years old, 30000 m^2 for three years old and 40000 m^2 for four and five years old seedling were separated in the nursery. On the other hand, balanced seedling production in consecutive years and consideration of demand increase or decrease on the seedling production at any ages were main goals. For this, developed model was solved in three different formats deal with rapid demand increase (RDI), slow demand increase (SDI) and demand decrease (DD) scenarios.

Main results: Obtained results showed that if there is a rapid increase in demand, largest present value was 385310 $ and total produced seedling number was 905262. Realization of slow demand increase has led to reduction of 6658 $ (1.73%) in present value, and 17461 piece in produced seedling number. However, reduction of demand decrease caused to occur present value 24989 $ (1.93%) and produced seedling number 61479 piece (6.79%) less.

Research highlights: By controlling the seedling production amount and process, more effective usage of nursery area can be possible as well. By the way it can be possible to endure nursery costs and reach quality targets more efficiently.

Keywords: Seedling, Nursery, Seedling production, Linear programming, Optimization.

Türkiye'de devlet orman fidanlıklarında Karaçam (*Pinus nigra*) ve Kızılçam (*Pinus brutia)*) fidanı üretiminin optimizasyonu

Özet

Çalışmanın amacı: Bu çalışmada, doğrusal programlama kullanılarak farklı yaşta karaçam (*Pinus nigra*) ve kızılçam (*Pinus brutia*) fidan üretimi planlanmış ve fidan satış gelirinin maksimize edilmesi amaçlanmıştır.

Materyal ve Yöntem: Bunun için; fidanlık alanında, ilk yıl 10,000 m^2, ikinci yıl 20,000 m^2, üçüncü yıl 30,000 m^2, dördüncü ve beşinci yıl için 40,000 m^2 alan ayrılmıştır. Ayrıca; kızılçam/karaçam fidanının birbirini izleyen yıllarda dengeli üretilmesi; herhangi bir yaştaki kızılçam/karaçam fidan üretiminde talep artışı veya azalışının göz önünde bulundurulması hedeflenmiştir. Bunun için, geliştirilen model, hızlı talep artışı (HTA), yavaş talep artışı (YTA) ve talep azalışı (TA) senaryolarına göre üç ayrı biçimde çözülmüştür.

Sonuçlar: Çözüm sonucunda; hızlı talep artışı olması durumunda en büyük bugünkü değer ($385,310.00) ve fidan üretim düzeyi (905,262 adet) elde edilmiştir. Talep artışının yavaş gerçekleşmesi, bugünkü değerin $6,658 (%1.73), fidan üretiminin 17,461 (%1.93) adet; talep hızının azalması ise bugünkü değerin $24,989 (%1.93), fidan üretiminin 61,479 adet (%6.79) daha az gerçekleşmesine yol açmıştır.

Araştırma vurguları: Üretim miktarını ve sürecini kontrol ederek fidanlık alanının daha etkin kullanılması mümkündür. Böylece fidanlık maliyetlerini azaltmak ve kalite hedeflerine daha etkin ulaşmak mümkün olabilir.

Anahtar Kelimeler: Fidan, Fidanlık, Fidan üretimi, Doğrusal programlama, Optimizasyon.

Introduction

A well-functioning forestry seedling nursery sector is essential for plantation expansion, while seedling production is a critical first step in the timber supply chain (Harrison et al., 2008). State nursery enterprises have many problems in Turkey such as capacity utilization, facility location, employment, seedling cost and sale price, finance, mechanization, governance and organization (Alkan, 2009). Productivity problems are also possible in these enterprises (Alkan, 2003).

Nursery enterprises are establishments with field and greenhouse plants that produce some plant materials, and they are established in various types according to their marketing goals (Ürgenç, 1999; Boydak & Çalışkan, 2014). Nursery field is divided into parcels. Afterwards, levelling, drainage and tillage are completed in nurseries. As bare-root seedlings can be produced in nurseries, seedlings can also be produced in tubes or containers by using some mixture of growing medium.

Seedling production in state forest nursery enterprises in Turkey is employed according to annual sowing, rotation and working programs which are organized within five years as a requirement of the planned work. In addition to the fact that nurseries make profit, they oversee other purposes such as serving for the benefit of society, meeting customer needs and desires, and creating employment. On the other hand, they have some problems such as lack of capacity utilization, facility location, and high number of non-value creating activities in production process, unproductivity in value creating activities, quality and cost. Therefore, present situation analysis must be performed and effective factors in management success and necessary precautions with regard to rational criteria in terms of management strategies must be determined in forest nursery enterprises (Alkan, 2003).

High quality and low cost are the most important criteria in nurseries. There are some costs as labor cost, material cost, machine operation, staff expenses, depreciation, land use prices etc. that enterprises have to endure in order to reach quality targets and carry on sustainability as well (Alkan, 2000; Alkan, 2003). Thus, it is necessary to reveal and monitor the production costs in nursery and greenhouse enterprises for determining profitable growth conditions (Power et al., 1991).

In the literature, morphological quality criteria such as seedling height, root collar diameter, seedling height/root collar diameter ratio, and stem/root ratio have been examined and quality classifications have been studied (Genç et al., 1999; Demircioğlu et al., 2004; Atik 2013). In addition, seedling production techniques, costs and sales incomes have been evaluated (Séhouéto et al., 2015); seedling marketing models have been developed and economic analysis have been made (Emokaro et al., 2014); working conditions of the nursery staff have been examined (Ünver-Okan & Kaya, 2015); analysis of the nursery sector has been made (Gregorio et.al, 2015); integer programming has been used in solution of seedling production and distribution problem (Rantala, 2004).

Though effective and profitable managing of nursery enterprises that constitutes the basis of reforestation efforts is very important, there has not been any study on the optimization of seedling production in the state forest nursery enterprises in Turkey. In the nursery industry, cost-effectiveness has, perhaps for historical reasons, usually been of secondary concern while more attention has been paid to biological issues (Rantala, 2004).

In this study, applicability of a linear model in rationalization of nurseries is examined. *Pinus brutia* and *Pinus nigra* seedlings production at different ages were projected in the study, and maximization of seedling sales revenues was the primary goal. Balanced seedling production in consecutive years and consideration of demand increase or decrease on the Turkish red pine and Anatolian black pine seedling production at any ages were also aimed.

Material and Method

In this study, sales price of the seedlings as of 21.01.2016 (“Seedling Sales Price”, 2016) were used in linear programming model as a material (Table 1).

Table 1. Seedling sales prices in 2016

Tree Species	Seedling Age				
	1	2	3	4	5
	Sales Price (R_i , $/number)				
Pinus brutia	0.27	0.32	0.49	0.69	0.85
Pinus nigra	0.24	0.31	0.49	0.69	0.85

The model was solved in different ways based on different target values and the assumptions used in the model were set up as follows:

- Forest nursery enterprise is willing to produce one, two, three, four and five years old seedlings between 2017 and 2021 years, and to maximize seedling sales revenues.
- Seedlings will be produced in polythene pots or plastic containers in different size such as 15x15 cm, 18x30 cm, 30x40 cm, 40x40 cm. Fields varied in sizes such as 10000 m^2 area for one year old, 20000 m^2 for two years old, 30000 m^2 for three years old and 40000 m^2 for four and five years old seedlings in the nursery.
- It is required to produce at least number of 150000 Turkish red pine and 100000 Anatolian black pine seedlings at one year old.
- The difference between seedling numbers of Turkish red pine/Anatolian black pine at one, two, three, four and five years old should be maximum ±20%.
- The number of the produced Turkish red pine and Anatolian black pine seedlings at any age in consecutive years should be;

a) 1.2-1.5 times more than seedling production amount of previous year at the same age [Rapid demand increase (RDI)],
b) 1.0-1.1 times more than seedling production amount of previous year at the same age [Slow demand increase (SDI)],
c) 0.85-0.95 times more than seedling production amount of previous year at the same age [Demand decrease (DD)].

Purpose equation

Purpose equation was defined as maximization of the total present value of Turkish red pine and Anatolian black pine seedling sales revenues between 2017-2021 years and formulated as given below.

$$Z_{\max} = \sum_{i=1}^{5}\sum_{j=i}^{5} c_{ij}x_{ij} + \sum_{i=1}^{5}\sum_{j=i}^{5} c_{ij}y_{ij} \qquad (1)$$

x_{ij} = *Number of the "i" aged Turkish red pine seedling at "j" year,*

y_{ij} = *Number of the "i" aged Anatolian black pine seedling at "j" year,*

c_{ij} =*Present value of "i" aged Turkish red pine/Anatolian black pine seedlings produced in "j" year (* $c_{ij} = R_i/(1+r)^j$ *; r (discounted rate)=2%)*

<u>Constraints</u>

Area constraint was defined as:

$$\sum_{i=1}^{n} a_i x_{ij} + \sum_{i=1}^{n} a_i y_{ij} = b_j \quad (j = 1,2,...,5) \qquad (2)$$

a_i = *Separated area for production of Turkish red pine/Anatolian black pine seedlings at "i" age (m*^{2}*/number)*

b_j = *Total separated area for production of Turkish red pine/Anatolian black pine seedlings in "j" year (m*^{2}*).*

Number of seedling constraints was defined as:

$$\sum_{j=1}^{n} x_{ij} - B_i = 0 \quad (i = 1,2,...,5) \qquad (3)$$

$$\sum_{j=1}^{n} y_{ij} - N_i = 0 \quad (i = 1,2,...,5) \qquad (4)$$

B_i = *Number of total Turkish red pine seedling to be produced at "i" age*

N_i = *Number of total Anatolian black pine seedling to be produced at "i" age*

Production amount constraints were expressed as:

$$B_1 \geq 150000$$

$$N_1 \geq 100000$$

Constraint defined as the difference between seedling numbers of *Pinus brutia*/*Pinus nigra* at one, two, three, four and five years old was expressed as follows:

$$-0.8B_i + B_{i+1} \geq 0 \ (i = 1,2...,4)$$

$$-1.2B_i + B_{i+1} \leq 0 \ (i = 1,2...,4)$$

$$-0.8N_i + N_{i+1} \geq 0 \ (i = 1,2...,4)$$

$$-1.2N_i + N_{i+1} \leq 0 \ (i = 1,2...,4)$$

Production flow constraints based on the changes in the level of demand was expressed as follows:

a) Rapid demand increase (RDI):

$$-1.5x_{ij-1} + x_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-1.5y_{ij-1} + y_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-1.2x_{ij-1} + x_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-1.2y_{ij-1} + y_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

b) Slow demand increase (SDI):

$$-1.1x_{ij-1} + x_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-1.1y_{ij-1} + y_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-x_{ij-1} + x_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-y_{ij-1} + y_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

c) Demand decrease (DD):

$$-0.95x_{ij-1} + x_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-0.95y_{ij-1} + y_{ij} \leq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-0.85x_{ij-1} + x_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

$$-0.85y_{ij-1} + y_{ij} \geq 0$$

$$(i = 1,2...,4)\ , \ (j = i+1, i+2,..,i+5)$$

Equations and inequalities in the text constitute more than one constraint and variable. Therefore; Model consists of 73 constraints and 40 variables. For example; equation 2 consists of 5 constraints, equation 3 consists of 5 constraints and equation 4 consists of 5 constraints. So, the 2, 3 and 4 polynomial equations constitute a total of 15 constraints. Variable (xij) shows the production amount of fifteen *Pinus brutia* seedlings, (Bi) shows 5 count variables; variable (yij) shows the production amount of 15 *Pinus nigra* seedlings and (Ni) shows 5 counting variables. In this way, linear programming model was obtained which was resulting from 40 variables and 73 constraints including area size, seedling number, production amount and flow.

Results

Models are resolved by using Microsoft Excel and solution summaries are given in Table 2, 3 and 4. Obtained purpose equation value (the present value of total sales revenues) is $385310 in RDI scenario. Purpose equation value is 1.73 % less than this value in SDI scenario and 6.49 % less in DD scenario. Also, 905262 piece seedlings are produced between 2017-2021 years in RDI scenario and the seedling production amounts are 1.93 % and 6.79 % less in SDI and DD scenarios respectively.

According to Table 2, at least 100000 one year old *Pinus nigra* seedlings production constraint exceeded 19295 units more while at least 150000 one year old *Pinus brutia* seedling production constraint exceeded at targeted level. The difference between seedling numbers of *Pinus brutia/Pinus nigra* at one, two, three, four and five years old should be maximum ±20% constraint exceeded -20%. For example, two years old *Pinus brutia* seedling production amount was 80 % of the production amount of one year old *Pinus brutia* seedling. Constraint of *Pinus brutia* and *Pinus nigra* seedling production amount at any age that should be 1.2-1.5 times more than seedling production amount of previous year at the same age in consecutive years was also provided. For example, according to Table 2, in 2018, 2019 and 2020, *Pinus brutia* seedling production amount reached to 1.2 times more than the previous year amount and in the last year seedling production amount was reached to 1.5 times more than the previous year.

Table 2. Seedling production amount according to the RDI scenario

Year	Seedling age					Total
	1	2	3	4	5	
			Pinus brutia			
2017	18844					18844
2018	22613	22355				44968
2019	27136	26826	26374			80336
2020	32563	32191	31648	30720		127122
2021	48844	38629	37978	46080	61440	232971
Total (B_i)	150000	120001	96000	76800	61440	504241
			Pinus nigra			
2017	14987					14987
2018	17984	17502				35486
2019	21581	21002	20975			63558
2020	25897	25203	25170	24432		100702
2021	38846	31729	30203	36647	48863	186288
Total (N_i)	119295	95436	76348	61079	48863	401021
			Pinus brutia* and *Pinus nigra			
2017	33831					33831
2018	40597	39857				80454
2019	48717	47828	47349			143894
2020	58460	57394	56818	55152		227824
2021	87690	70358	68181	82727	110303	419259
Total	269295	215437	172348	137879	110303	905262
			Zmax=$385310			

According to Table 3, at least 100000 one year old *Pinus nigra* seedlings production constraint exceeded 14101 units more. However, at least 150000 one year old *Pinus brutia* seedling production constraint exceeded at targeted level. The difference between seedling numbers of *Pinus brutia/Pinus nigra* at one, two, three, four and five years old should be maximum ±20% constraint exceeded -20% same as in the RDI scenario. Two years old *Pinus brutia* seedling production amount was 80 % of the production amount of one year old *Pinus brutia* seedling. Constraint of *Pinus brutia* and *Pinus nigra* seedling production amount at any age that should be 1.0-1.1 times more than seedling production amount of previous year at the same age in consecutive years was also provided. As it is seen in Table 3, in 2018 and 2019, *Pinus brutia* seedling production amount was provided at the same level with the previous year and in 2020 and 2021, seedling production amount was reached to 1.1 times more than the previous year.

According to Table 4, at least 100000 one year old *Pinus nigra* seedlings production constraint exceeded 1007 units more and at least 150000 one year old *Pinus brutia* seedling production constraint exceeded at targeted level. The difference between seedling numbers of *Pinus brutia/Pinus nigra* at one, two, three, four and five years old should be maximum ±20% constraint exceeded -20% same as in the the RDI and SDI scenarios. Two years old *Pinus brutia* seedling production amount was 80% production amount of one year old *Pinus brutia* seedling.

Table 3. Seedling production amount according to the SDI scenario

Year	Seedling age					Total
	1	2	3	4	5	
			Pinus brutia			
2017	28249					28249
2018	28249	27842				56091
2019	28249	27842	29003			85094
2020	31073	30626	31903	36571		130173
2021	34181	33689	35094	40229	61440	204633
Total (B_i)	150001	119999	96000	76800	61440	504240
			Pinus nigra			
2017	21488					21488
2018	21488	21179				42667
2019	21488	21179	22062			64729
2020	23637	23297	24268	27819		99021
2021	26000	25626	26694	30601	46735	155656
Total (N_i)	114101	91281	73024	58420	46735	383561
			Pinus brutia and *Pinus nigra*			
2017	49737					49737
2018	49737	49021				98758
2019	49737	49021	51065			149823
2020	54710	53923	56171	64390		229194
2021	60181	59315	61788	70830	108175	360289
Total	264102	211280	169024	135220	108175	887801
			Zmax=$378652			

Table 4. Seedling production amount according to DD scenario

Year	Seedling age					Total
	1	2	3	4	5	
			Pinus brutia			
2017	36115					36115
2018	30698	32346				63044
2019	29163	30729	33655			93547
2020	27705	29192	31972	39385		128254
2021	26320	27733	30373	37415	61440	183281
Total (B_i)	150001	120000	96000	76800	61440	504241
			Pinus nigra			
2017	24319					24319
2018	20671	21781				42452
2019	19638	20692	22662			62992
2020	18656	19657	21529	26521		86363
2021	17723	18674	20452	25195	41372	123416
Total (N_i)	101007	80804	64643	51716	41372	339542
			Pinus brutia and *Pinus nigra*			
2017	60434					60434
2018	51369	54127				105496
2019	48801	51421	56317			156539
2020	46361	48849	53501	65906		214617
2021	44043	46407	50825	62610	102812	306697
Total	251008	200804	160643	128516	102812	843783
			Zmax=$360321			

Constraint of *Pinus brutia* and *Pinus nigra* seedling production amount at any age that should be 0.85-0.95 times of the seedling production amount of previous year at the same age in consecutive years was also provided. For example, according to Table 4, in 2018, 2019 and 2020, *Pinus brutia* seedling production amount reached to 0.85 times more than the previous year amount and in 2019, 2020 and 2021, seedling production amount was reached to 0.95 times more than the previous year.

Field constraint target values and field values used in seedling production according to model solutions are given in Table 5 Decrease in the demand rate caused difference in the field size in seedling production. For example, while 6446 m^2 is used in 2017 in RDI scenario, field size is 808 m^2 more in SDI scenario and 1195 m^2 more in DD scenario. While the amount used in the last three years is decreasing.

Table 5. Field sizes used in the model

Year	Target value (most, m^2)	RDI (m^2)	SDI (m^2)	DD (m^2)
2017	10000	6446	7254	7641
2018	20000	18773	19803	20000
2019	30000	30000	30000	29265
2020	40000	40000	39047	36424
2021	40000	38462	34999	31272

Discussion and Conclusion

There is still plenty of room for further improvements in controlling supply chain systems, despite the considerable advances that have occurred throughout the years (Sarimveis et al., 2008). The most important solution approaches for supply chain problems are based on discrete mathematical programming and continuous approximations (Rantala 2004). Due to their dynamic and uncertain nature, production and inventory problems can be naturally formulated as dynamic programs. Demand uncertainty is one of the major factors affecting the decision making in production and control (Sarimveis et al., 2008). The main purpose of the nursery enterprise is to produce the well-rooted, layered, healthy and stabile seedlings in a short period as soon as possible (Saatçioğlu, 1976). However, conditions that will provide quality seedling production in our country are not fully provided in state forest nurseries (Alkan, 2000). In countries with high inflation rates, accessibility to macro-level afforestation targets with budgetary conditions is of great importance. It is accepted as hypothetical that the work items related to the seedling production process in each nursery have some method etudes within themselves (İlter et al., 1988).

Rantala (2004) emphasized that according to the developed optimizing model, compared to the company's current supply chain strategy with 5 nursery units producing seedlings, when other supply chain strategies were applied the number of nursery units decreased by 2-4 units, and cost savings in the supply chain varied from 11.3% to 21.3%. Perea-López et al. (2003) compared the behaviour of a supply chain under centralized and decentralized management approaches, and showed that the former yields better results, with profit increases of up to 15%. Boukas and Liu (2001), investigated a continuous-time inventory-production planning problem, where the products deteriorate and their value reduces with time. Chen et al. (2006) formulated the profit-maximization problem as dynamic programming model and showed that the percentage of profit difference between the two policies increases significantly in demand parameters and production unit cost.

By maximization of seedling sales revenues, balancing seedling production in consecutive years and considering demand increase or decrease on *Pinus brutia* and *Pinus nigra* seedling production at any ages as given in the methodology, it can be possible to solve production process in nurseries by mathematical models. We have presented that seedling production in nurseries can be planned by using mathematical models like linear programming. By controlling the seedling production amount and process, more effective usage of nursery area can be possible as well. By the way it can be possible to endure nursery costs and reach quality targets more efficiently. This is very important in terms of the sustainability of nursery enterprises.

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