Seed Crop Investigations of *Pinus sylvestris*, *Pinus nigra* subsp. *pallasiana* and *Pinus brutia* in Turkey

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Abstract

This article describes the quantity and quality of seed yields, their annual variations, and periodic dispersal within the year for populations of different site classes, age categories, and elevations together with the effects of silvicultural treatments in *Pinus sylvestris, Pinus nigra* subsp. *pallasiana,* and *Pinus brutia* in Turkey. Seed crop per unit area (square meter) was measured at sample plots which were chosen from even-aged, pure pine stands with a normal, even-aged structure by using pyramid-shaped metal seed traps mounted on a wooden or metal frame. The results revealed that seed yield was higher in good site classes. In general, annual fluctations of seed crops were in the same direction during each year in all sample plots for a given species. Populations of middle age of each tree species generally produce more seeds for the same site classes and elevation zones. The pine species with lighter seed weights produced greater seed yields (numbers). Seed crops at the middle elevation zone were more abundant than lower and/or upper elevation zones.

Rhythms of seed dispersal generally occured during the same periods within each year for each tree species. These rhythms are well correlated with climatic conditions and the geographic distribution of the species to enable it to secure future generations.

In general, empty seed percentages were positively correlated with poor site classes, poor seed years, very old stands, and higher elevations.

Keywords: Seed crop, seed dispersal, Pinus sylvestris, Pinus nigra subsp.pallasiana, Pinus brutia

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1. Introduction

The seed is the starting point of many natural and artificial regeneration methods in forestry. For natural regeneration from seeds, the quantity and quality of seed crops, their annual fluctuations, periodic dispersals within and among years, and variations among populations neccesitate detailed knowledge. For artificial regeneration where seeds are collected from stands, other factors such as the interaction between seed years and labor costs must also be considered. Moreover, when advanced tree breeding is undertaken, the seed is also the focal point.

Pinus brutia (4.2 million ha.), *Pinus nigra* subsp. *pallasiana* (3.3 million ha.), and *Pinus sylvestris* (1.0 million ha.) cover 41 % of Turkey's forest area and have been the subject of many seed crop investigations. About 76 % of the country's annual plantation establishment of 100.000 ha. have been of these pine species (Anonymus, 2001; Urgenc et al. 1993). Besides a priority for research, was also given to tree breeding of these three pine species. These tree breeding researches included selection of seed stands and plus trees, establishment of seed orchards, and testing the progeny (Koski and Antola, 1994; Boydak and Çalıkoglu, 2000; Öztürk et al. 2007; Öztürk et al. 2008; Alan et al. 2008).

This article describes the seeding characteristics of *Pinus sylvestris*, *Pinus nigra* subsp. *pallasiana* and *Pinus brutia* in Turkey. It describes the methods of seed collection; the quantity, quality, and annual variations of seed yields; and the variations in dispersal for species populations of different site classes, age catagories, elevations, and silvicultural treatments.

2. Materials and Methods

2.1. Seed collecting and counting methods

Great advancement in the forest seed crop research methods of forest trees have been made, especially during the first part of 20th century. Seed traps were developed by Russian forest scientists (Morosow, 1928; Sarvas, 1962) and have been a great advancement in seed crop research. Box-shaped seed traps, first used by Orlow, Samarajew and Sorosh (Morosow, 1928), were a shallow, square box with wooden rims and a cloth or wire screen bottom to eliminate the rainwater (Sarvas, 1962). Modified versions of this trap were later used in the Northern European countries (Sarvas, 1962), the United States (Fowells and Schobert, 1956), and Turkey (Saatçioğlu, 1970). Ogijewski used funnel-shaped traps with lower tips that entered to the ground to avoid seed predation by birds and removal or dessication by wind (Morosow, 1928). The results obtained by the funnel-shaped traps were 20 % - 30 % greater than from boxes (Sarvas, 1962 after Tolsky). Sarvas (1962) later used funnel-shaped metal seed traps mounted on three way pedestals a wooden frame 130 cm above the ground surface. A

bent cloth bag at the bottom collected and protected the seeds. In Turkey, metal seed traps shaped like an inverted pyramid with a bag at the bottom were mounted on wooden or metal frame about 85 - 90 cm above the ground. They were first introduced in 1970 for *Pinus sylvestris* seed crop research (Boydak, 1975; Boydak, 1977), and were then used for research with other species (Urgenc, 1977; Urgenc et al., 1989;Tosun 1992; Boydak et al. 2002).

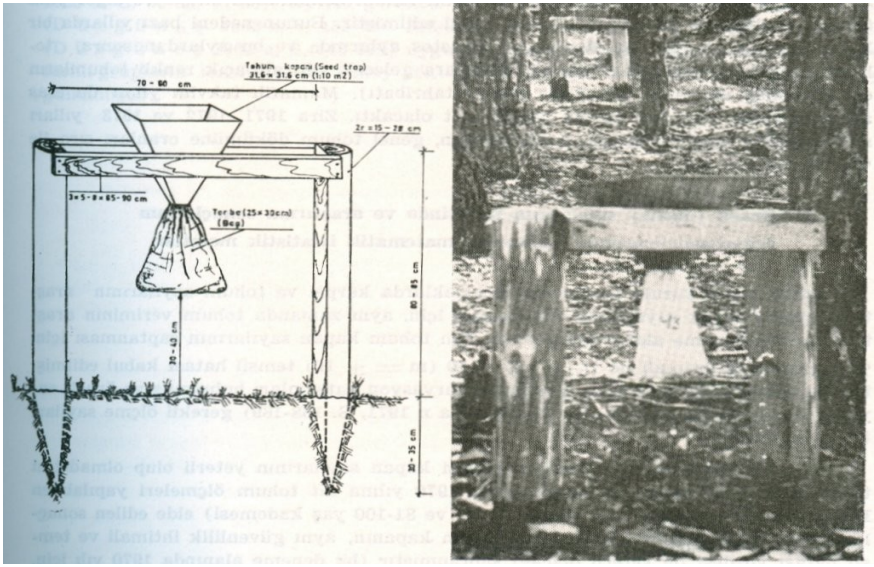

Figure 1. Left. Seed trap diagram Right: Seed traps placed systematically in a scots pine stand (Photo: M. Boydak)

Şekil 1. Sol. Tohum kapanı şematik olarak Sağ: Sarıçam meşceresinde sistematik olarak yerleştirilmiş tohum kapanları (Foto: M. Boydak)

Numbers of seeds per unit area (square meter) were measured at sample plots chosen from even - aged pure pine stands of average structures by using box-shaped metal seed traps (Figure 1 a, b). Each sample plot had an area of 0.25 hectare (50 x 50 m). Nearly all seeds that fall in a seed trap come from the surrounding trees within a distance from the trap equal to about stand top height. Consequently, the area of seed collection was considered to be about 1-1,5 hectares - the sample plot together with its surrounding area. If thinnings (silvicultural treatments) were applied to choosen sample plots, the surrounding areas were also thinned. In forest seed crop research the confidence limits and accuracy for a given population depend on the numbers of seed traps, their surface area, and the seed crop abundance of the population. A 90 percent confidence limit (t = 1.6) and 10 percent accuracy (m = ± 10) were considered desirable for the seed collection. In *Pinus sylvestris* stands 20 seed traps, each with a surface area of 1/10 square meter, were systematically placed in the sample plots of middle aged and

older selected stands, while 30 traps were placed in each young populations (Boydak, 1977). The desired accuracy was achieved in good seed years of *Pinus sylvestris*; and the accuracy was between 15 % and 20 % during medium seed years, slightly below the desired level. The accuracy during poor seed years was far outside of this confidence limit and accuracy. Consequently, numbers of seed traps were increased to 25 for the subsequent investigations of *Pinus nigra* subsp. *pallasiana* (Boydak et al. 2002) and *Pinus brutia* (Urgenç, 1977). In a second research of *Pinus brutia*, 24 seed traps with a 0.25 square meter surface area were used (Urgenç et al. 1989).

2. 2. Study sites of the species

Scots Pine (*Pinus sylvestris L.*): The study area was located in the Sündiken Mountains in Eskişehir-Çatacık forest region, one of the southern-most boundaries (39° 57´ N latitude) of the natural distribution of scots pine (Figure 2). Fifteen sample plots were established in the pure, uniform *Pinus sylvestris* stands across a range of site classes and ages. These site classes are indicators of site productivity (i.e., wood production) and are determined according to the top height and age of the each population. Eleven plots were from “good” and 4 were from “medium” and “poor” site classes. The plots were generally at middle elevations (1380-1630 m) of the *Pinus sylvestris* natural distribution in this region (Table 1). Sample plots were generally selected from the silviculturally less treated (thinned) populations, except two plots (No. VIII and X) which were heavily thinned. A heavy, low thinning was applied to three sample plots (No. VII, VIII, and IX) at the beginning of the research to investigate the effects of thinning on seed crops. Seed traps were emptied 7 times a year to determine the within-year periodic rhythm of seed dispersal. The research was continued between the years 1971 and 1973 (Boydak, 1975; Boydak, 1977).

Figure 2. Location of the seed crop researches areas in Turkey (1: Eskisehir-Catacık; 2: Balıkesır-Dursunbey; 3: Antalya).

Şekil 2. Türkiye'de tohum verimi çalışmlarının yapıldığı alanların konumları. (1:Eskişehir-Çatacık; 2: Balıkesir-Dursunbey; 3: Antalya).

Black Pine *(Pinus nigra* Arnold subsp. *pallasiana (Lamb.) Holmboe)*: The study area was located in the Dursunbey and Alaçam-Balıkesir forest regions of Turkey (Figure 2). Eleven sample plots were chosen from pure black pine stands (Table 2). Ten of these sample plots were in the upper elevation belt (1430-1510 m). Moderate and intensive silvicultural treatments were applied to two of the three sample plots of each age category (55-65; 120-130; 140-150 years) within the upper belt. These plots were in the highest or near the upper limit of the second highest site class. Also in this belt was another sample plot of the fourth site class in the 140-150-year age category. Within the middle elevation belt (830 m), a sample plot in highest site class at the 55 - 65 year age category were also chosen for comparision. Seed traps were emptied 5 times a year. The research was continued between the years 1972 and 1978 (Boydak et al. 2002).

Table 1. Seed crop variation of *Pinus sylvestris* in different years at sample plots (Boydak, 1977)

Tablo 1. Sarıçam deneme alanlarında tohum veriminin yıllara gore değişimi (Boydak, 1977)

Sample Plot No.	Age	Site Class	Elevation m	Crown coverage	Seed	Years 1970-1971 (1971) Empty	1970-1971 (1971) Total	1971-1972 (1972) Empty	1971-1972 (1972) Total	1972-1973 (1973) Empty	1972-1973 (1973) Total	Average Empty	Average Total
I	81	Good	1550	0.53	Per sq.m	-	-	33	155	3	12	18	83
					%	-	-	21	100	25	100	23	100
II	81	Good	1510	0.54	Per sq.m	108	384	45	143	2	7	52	178
					%	28	100	31	100	29	100	29	100
III	82	Good	1440	0.53	Per sq.m	70	286	22	115	6	13	33	138
					%	24	100	19	100	46	100	30	100
IV	85	Poor	1530	0.50	Per sq.m	40	223	11	52	2	4	18	93
					%	18	100	21	100	50	100	30	100
V	85	Poor	1510	0.55	Per sq.m	52	206	18	47*	-	1*	23	84
					%	25	100	38	100	-	100	21	100
VI	86	Medium	1530	0.52	Per sq.m	74	265	22	99	1	5	32	123
					%	28	100	22	100	20	100	23	100
VII	81	Good	1530	0.42	Per sq.m	63	224	18	114	5	15	29	118
					%	28	100	16	100	33	100	26	100
VIII	81	Good	1530	0.48	Per sq.m	118	400*	67	272*	4	17	63	230
					%	29	100	25	100	24	100	26	100
IX	82	Good	1470	0.41	Per sq.m	34	171	23	122	9	29	22	107
					%	20	100	19	100	31	100	23	100
X	85	Good	1480	0.48	Per sq.m	-	-	45	185	14	84*	30	135
					%	-	-	24	100	17	100	20	100
XI	125	Good	1380	0.42	Per sq.m	102	270	33	145	9	32	48	149
					%	38	100	23	100	28	100	30	100
XII	198	Medium	1530	0.48	Per sq.m	78	198	63	159	13	37	51	131
					%	39	100	40	100	35	100	38	100
XIII	185	Good	1430	0.27	Per sq.m	71	232	29	115	12	47	37	134
					%	31	100	25	100	26	100	27	100
XIV	61	Good	1610	0.50	Per sq.m	43	271	24	109	5	20	24	133
					%	16	10	22	100	25	100	21	100
XV	46	Good	1630	0.46	Per sq.m	27	163*	16	68	5	26	16	86
					%	17	100	24	100	19	100	19	100
Total Average					Per sq.m	68	254	30	125	6	23	35	134
					%	26	100	25	100	27	100	26	100

* indicates the maximum and the minimum seed numbers of that year

* İlgili yıldaki maximum ve minimum tohum sayılarını gösterir

Table 2. Seed crop variation of Anatiolian black pine in different years at sample plots (Boydak et al., 2002)
Tablo 2. Anadolu Karaçamı deneme alanlarında tohum veriminin yıllara gore değişimi (Boydak ve Ark., 2002)

Sample Plot No Upper belt	Age	Site Class	Elevation m	Crown Coverage		Seed	1972		1973		1974		1975		1977		1978		Average	
				Before Treat.	After Treat.		Empty	Total	Empty	Total	Empty	Total	Empty	Total	Empty	Total	Empty	Total	Empty	Total
I (Control)	63	I	1450	0.51	-	Per sqm	20	71	5	10	6	8	2	5	2	23	4	15	6	21
						%	28	100	50	100	75	100	40	100	9	100	27	100	29	100
II (Moderate)	67	I	1510	0.58	0.50	Per sqm	22	93	8	18	6	11	3	4	9	52	4	15	9	31
						%	24	100	13	100	55	100	75	100	17	100	27	100	26	100
III (Intensive)	55	I	1510	0.57	0.50	Per sqm	29	151	8	18	2	8	6	13	-	21	4	17	8	38
						%	19	100	44	100	25	100	46	100		100	24	100	21	100
IV (Control)	122	II	1460	0.58	-	Per sqm	66	185	3	7	10	28	28	77	4	25	6	34	20	59
						%	36	100	43	100	36	100	36	100	16	100	18	100	32	100
V (Moderate)	129	II	1480	0.50	0.43	Per sqm	48	140	1	1	4	19	13	40	6	15	4	30	13	41
						%	34	100	100	100	21	100	32	100	40	100	13	100	32	100
VI (Intensive)	123	II	1440	0.39	0.20	Per sqm	56	175	1	3	15	45	27	78	5	26	6	57	18	64
						%	32	100	33	100	33	100	35	100	19	100	11	100	28	100
VII (Control)	145	II	1440	0.56	-	Per sqm	70	240	9	13	6	11	14	22					25	72
						%	29	100	69	100	55	100	64	100	-	-	-	-	36	100
VIII (Moderate)	140	II	1440	0.52	0.40	Per sqm	56	175	6	21	6	10	15	19					21	56
						%	32	100	29	100	60	100	79	100	-	-	-	-	37	100
IX (Intensive)	150	I	1430	0.37	0.12	Per sqm	69	233	4	6	3	10	8	12					21	65
						%	30	100	67	100	30	100	67	100	-	-	-	-	32	100
Average						Per sqm	48	162	5	10	6	16	13	30	4	27	5	28	16	50
						%	30	100	50	100	38	100	43	100	15	100	18	100	32	100
X (Control) Middle belt	55	I	830	0.65	-	Per sqm	45	339	25	135	15	47	33	186	15	39	12	62	25	135
						%	13	100	19	100	32	100	18	100	38	100	19	100	19	100
XI (Intensive) Upper belt	155	IV	1430	0.31	0.31	Per sqm	23	47	2	6	19	42	30	54	1	10	4	16	13	29
						%	49	100	33	100	45	100	56	100	10	100	25	100	45	100
Total Average						Per sqm	46	168	6	21	8	21	16	46	5	26	6	31	16	55
						%	27	100	29	100	38	100	35	100	19	10	19	100	29	100
																0				

Table 3. Seed crop variation of Turkish red pine in different years at sample plots (summarized from Ürgenç 1977)
Tablo 3. Kızılçam deneme alanlarında tohum veriminin yıllara gore değişimi (Ürgenç 1977'den özetlenmiştir)

Sample plot No.		Elevation m	Site Class	Age	Crown Coverage	1971		1972		1973		1974		Average	
						S.N.P	E.S.P	S.N.P	E.S.P	S.N.P	E.S.P	S.N.P	E.S.P	S.N.P	E.S.P
Lower Elevation	I	240	Good	32	-	14	26	47	14	78	3	127	1	66	11
	II	240	Good	34	-	10	-	28	4	64	1	235	1	84	1
	III	250	Good	58	0.6	7	19	4	30	8	-	13	-	8	12
	IV	250	Good	53	0.7	19	-	11	16	21	-	38	-	22	4
			Average			13	11	23	16	43	1	103	1	45	7
Mid. Elev.	V	800	Good	76	0.5	43	31	74	16	104	1	45	-	66	12
	VI	800	Good	79	0.5	30	25	65	8	94	-	41	-	57	8
			Average			37	28	70	12	99	1	43	-	61	10
Total Average						25	19	46	14	71	1	73	1	53	8

S.N.P = number of seeds per square meter, E.S.P = empty seed percentages;
S.N.P = metrekaredeki tohum sayısı, E.S.P = Boş tohum yüzdesi

Turkish Red Pine (*Pinus brutia* Ten.): Two research studies were undertaken on the seed crops of *Pinus brutia* in the Antalya region (Figure 2). The first study occurred between 1971 - 1974 (Ürgenç, 1977), and the second was between 1979-1987 (Ürgenç et al., 1989). In the first study, 4 sample plots were established in pure *Pinus brutia* populations at the lower elevation belt (290-330 m), while 2 sample plots were established at the middle elevation belt (800 m) (Table 3). Seed traps were emptied 12 times a year (Ürgenç, 1977). In the second study, sample plots were established in 3 age classes (20, 40, and 60 years; Table 4) in both lower and higher elevation belts. Nine sample plots were established at the lower elevation (Antalya-Düzlerçamı; 290-330 m) and 9 plots were established at the higher elevation (Antalya-Hacıbekar; 1070-1200 m). Moderate and intensive thinnings were applied two of the three sample plots of each age category at both lower and higher elevation belts. Later, 3 sample plots at age category of 60 were also established at a middle elevation belt (Antalya-Bucak, 800-850 m). Stands of the middle belt were not treated (thinned) silviculturaly. Seed traps were emptied 9 times a year (Urgenç et al., 1989).

3. Results

Pinus sylvestris: Seed yields and their annual variation of different scots pine stands are shown in Table 1. Average minimum and maximum numbers of seeds per square meter were between 163-400, 47-272 and 1-84 in 15 populations in the years 1971, 1972, and 1973, respectively.

Seed yields of different site classes and age categories are shown in Figure 3. The results reveal that seed yield in general was higher in good site classes in both age categories, but differences between classes were greater in good seed years.

Seed yields of different age categories of different site classes are shown in Figure 3. According to Figure 3, seed yield of 81-100-year age category was generally higher than younger and older age categories in good site class for each year.

Table 4. Seed crop variation of Turkish red pine in different years at sample plots (summarized from Ürgenç et al. 1989)
Tablo 4. Kızılçam deneme alanlarında tohum veriminin yıllara gore değişimi (Ürgenç ve Ark. 1989'dan özetlenmiştir)

Zone, Locality and Elevation	Age	Years								
		1979	1980	1981	1982	1983	1984	1985	1986	1987
Lower elevation Antalya-Düzlerçamı (290-330 m)	20	24	18	51	58	27	30	-	-	-
	40	27	17	116	78	31	33	16	25	11
	60	7	4	26	44	18	26	19	17	10
	Average	19	13	64	60	25	30	17	21	10
	Empty seed (%)	4	*13*	*18*	*8*	*11*	*11*	*14*	*11*	*5*
Higher elevation Antalya-Hacıbekar (1070-1200 m)	20	1	1	2	6	4	3	-	-	-
	40	6	2	7	20	5	12	14	46	21
	60	6	2	7	12	3	12	11	29	22
	Average	4	2	5	13	4	9	12	37	21
	Empty seed (%)	*18*	*16*	*15*	*8*	*13*	*17*	*13*	*11*	*12*
Middle elevation Antalya-Bucak (800-850 m)	60	-	-	-	-	-	-	83	44	22
	Average	-	-	-	-	-	-	83	44	22
	Empty seed (%)	-	-	-	-	-	-	9	12	11
Total Average		12	8	35	37	15	20	38	34	18
Empty seed (%)		*11*	*15*	*17*	*8*	*12*	*14*	*12*	*11*	*9*

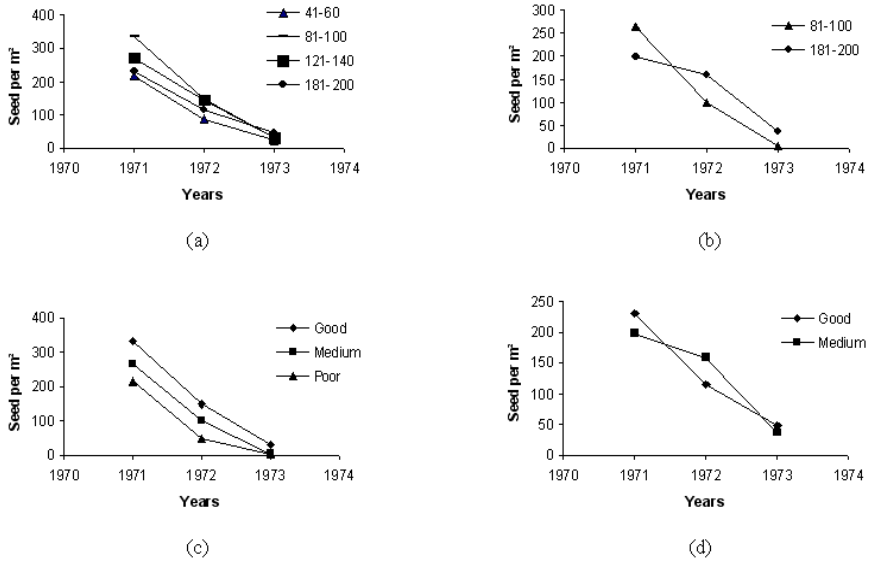

Figure 3: Effects of site and age classes on the seed crop of scots pine. a) Age class categories on good site, b)81-100 and 181-200 age classes on medium site , c) three site classes of 81-100 age class and d) two site classes of 181-200 age class (adapted from Boydak, 1977).

Şekil 3: Sarıçamda bonitet ve yaş sınıflarının tohum verimine etkisi a) iyi bonitet sınıfında yaş sınıfları b) Orta bonitet sınıfında 81-100 ve 181-200 yaş sınıfları c) 81-100 yaş sınıflarında üç bonitet d) 181-200 yaş sınıfında iki bonitet (Boydak, 1977'den uyarlanmıştır)

Annual periodical rhythm of the seed dispersal is shown in Figure 4a. Seed shedding of scots pine occured almost completely during the spring at Çatacık, where the maximum shedding was in April. As an average of 15 populations; 45 percent, 60 percent and 39 percent of the total crop were dispersed in April in the years 1971, 1972 and 1973, respectively.

As an average, empty seed percentage varied between 20-38 % in the sample plots, with a total average of 26%.

***Pinus nigra* subsp. *pallasiana*:** Seed yields and their annual variations of different black pine stands are shown in Table 2. The most abundant seed crop was obtained from the population of the 55 - 65 age category (X) of the middle elevation belt (830 m) in each year. This crop was many times higher than any age category of the upper elevation belt during the study period. In the upper elevation belt, the average minimum and maximum numbers of seeds per square meter were between 71-240, 1-21, 8 - 45, 4 - 78, 15 - 52, 15 - 57 in the years of 1972, 1973, 1974, 1975, 1977 and 1978, respectively. Also in the upper elevation belt, the total average seed crops of old age categories (140 - 150) were higher than younger age categories (55 - 65) between the years 1972 - 1978 (Table 2). Seed shedding of black pine occured almost completely during the spring at Balıkesir-Dursunbey. The total average maximum seed shedding occured in April (37 %), nearly equalled by the January-February period (36 %). Average empty seed percentages of all

years and sample plots varied between 19-45 %. The percentage of empty seeds was 29 % as the total average.

***Pinus brutia*:** *Pinus brutia* seed yields and their annual variations of *Pinus brutia* between the years 1971-1974 (Urgenç, 1977) and 1979-1987 (Urgenç et al., 1989; Boydak et al., 2006 a;b) are shown in Tables 3 and 4. The results of Urgenç (1977) show that seed crops of middle elevation populations were more abundant than the lower elevation populations except during one year (1974) (Table 3). The results (Urgenç, 1977) also show that seed dispersal takes place throughout the year and mainly during the July-December period, (with a maximum in August; Figure 4c). Average empty seed percentages varied between 1- 31 %, with 8 % as the total average (Table 3). Generally, empty seed percentages seemed to increase as the seed number per square meter decreased.

According to the second *Pinus brutia* study (Ürgenç et al., 1989), maximum seed crop was also obtained at the middle elevation belt (Table 4). This was followed by lower and higher elevation belts, respectively. Seed crops of the middle age category (40 years) was in general higher than the 20- and 60-year age categories at both lower and higher elevation belts (Table 4). Seed distrubution occured through out the year with maximum dispersal in August and the great majority of seeds dispersed within the July-December period (Figure 4d). Considering all elevations, average empty seed percentages varied between 8-17 %, with 11.7 % as the total average percentage of empty seeds.

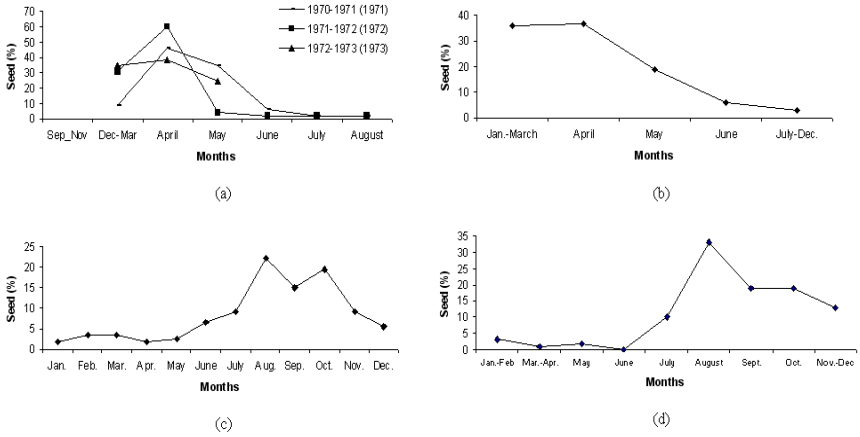

Figure 4: Annual periodic seed fall of the Pine species [a: Scots Pine (adapted from Boydak, 1977); b: Black Pine (adapted from Boydak et. al. 2002); c: Turkish Red Pine (adapted from Urgenç 1977); d: Turkish Red Pine (adapted from Urgenç et al. 1989)].

Şekil 4: Çam türlerinde n tohum dökümünün yıl içindeki değişimi [a:Sarıçam (Boydak 1977'den uyarlanmıştır; b: Anadolu Karaçamı (Boydak ve Ark., 2002'den uyralanmıştır; c: Kızılçam (Urgenç ve Ark. 1989'dan uyarlanmıştır)]

4. Discussion

4.1. Seed years

***Pinus sylvestris*:** In *P. sylvestris*, good (1971), medium (1972) and poor (1973) seed years followed each other (Table 1). In sample plot I the seed crop measurement in 1970 (153 seeds per square meters) was nearly equal to the seed crop of the same population in 1972 (155 seed per square meters; Boydak 1975, 1977). 1970 could also be accepted as a medium seed year in that plot. Although the data is limited, good or medium seed years seem to occur every two years in Eskişehir-Çatacık forest region. Other observations also suggested that good seed years occur every two or three years in *P. sylvestris* populations elsewhere in Turkey (Pamay, 1962; Saatçioğlu, 1971). In Spain, another southern distribution limit of *P. sylvestris*, good seed years also were observed every 2-3 years (Canellas et. al., 2000). On the other hand, frequency of good *P. sylvestris* seed years was reported as 4-6 years in Scotland (Matthews, 1971). Similarly, times between good seed years of this species in other Northern Euopean countries were also longer than the Eskişehir-Çatacık populations. Moreover, average seeds per square meter in Turkey were a few times greater than the Finnish *P. sylvestris* populations (Sarvas, 1962).

***Pinus nigra*:** It may be possible to infer from table 2 that *P. nigra* populations of Dursunbey-Alaçam have good seed years in 4-5 year- and in 2-3 year-intervals at upper and middle zones, respectively (Table 2). More research is needed to verify this periodicity, however.

***Pinus brutia*:** Because seeds from some closed cones drop after several years, the seeds dispersed each year by *P. brutia* may include seeds produced in different years. Some closed cones are set each year (Selik, 1963; Sefik, 1965; Boydak; 1993; Thanos, 2000; Thanos and Daskalakou, 2000); therefore, seed dispersal of any year does not include all of the seeds from the same flowering period. Instead, it also consists of seeds of some closed or half-opened cones of previous years.

Assuming 60 or more seeds per square meter is the criterion for a good seed year, good seed years occured every two or there years in the middle elevation zone of *Pinus brutia*, but occured every four years in the lower zone (Table 4). The higher elevation zone populations (Antalya-Hacıbekar) never produced enough seeds for any year between 1979-1987 to be considered as a good seed year. Besides inherent factors, poor seed crops at the higher elevations could be attributed to past inappropriate silvicultural treatments, poor crown development, or less than optimum site conditions. Either good seed years or medium seed years (40-60 seeds per square meter) generally occured every year, every three years, and every four years at medium, lower, and higher zones, respectively. (Thanos ad Daskalakou 2000, after Panetsos) also reported that above average seed crops were produced every 3 years in *Pinus brutia*; this result corresponds to results of lower elevation zone seed crops obtained from the present research.

All species: As the total average of the investigated years, *Pinus silvestris* produced 134 seeds per square meter (Table 1); *P. nigra*, 55 seeds (Table 2); and *P. brutia*, 53 seeds (Table 3). On the other hand, weight per 1000 seeds of these three species are 8,91 gr (Boydak 1977), 22,50 gr (Saatcioglu 1971), and 55,95 gr (Şefik 1965), respectively. Thus, the results indicate

that the species of smaller seed weights produce higher seed numbers (yields) among these three pine species.

In general, annual fluctuations of seed crops were in the same directions in different years in all sample plots for a given species. This result is consistent with previous research (Holmsgaard, 1972; Chalupka and Giertych, 1973).

4.2. Effect of elevation on seed crop

***Pinus sylvestris*:** Because the sample stands of *Pinus sylvestris* were distributed primarily in one elevation band (Table 1), it is not possible to make any interpretation of the effects of elevation on seed yields for this species.

***Pinus nigra*:** In *Pinus nigra*, middle zone seed yields were higher than higher zone yields (Table 2).

***Pinus brutia*:** In *Pinus brutia,* considerably higher seed crops were generally recorded from sample plots of the middle zone (Antalya-Bucak) than other zones during the measurement years (Table 3 & 4; Ürgenç, 1977; Ürgenç et al., 1989). Consequently, the middle zone elevations of 800-850 m appeared to represent the optimum condition for seed production of *Pinus brutia*. Besides inherent factors, these results could be altributed to the positive effects of a combination of better site classes and more compatible climatic conditions. Average seed crops from good site classes of the lower elevation zone (290-330 m) were greater than the averages from medium site classes of the higher zone (1070-1200 m; Ürgenç et al., 1989).

All species: The research results from both *Pinus brutia* and *Pinus nigra* indicate that seed yields from middle belt elevations were greater than from lower and/or upper elevations. The greater yields could be attributed to optimum ecological conditions leading to optimum flowering and pollination conditions in the middle elevation belt.

4.3. Effect of site class on seed crop yields

Seed crop yields per square meter from good site classes were generally considerably higher than yields from medium or poor sites of the same age ranges for all three pine species, probably because of the higher nutrient contents of the better site classes. This finding is supported by other studies (Sarvas, 1962; Smith et al., 1999). In *P. sylvestris* populations in Finland, seed yields increased as dominant heights increased, indicating increases with higher site classes. The number of seeds per square meter on poor sites of southern Finland (calluna type, 19 meters at 100 years) was 40, while it was 60 on sites of medium fertility (vaccinium type, dominant height 23 m. at 100 years), and 90 on more fertile sites (myrtillus and oxalis-myrtillus types, dominant height 27 m. at 100 years; Sarvas, 1962).

4.4. Effect of elevation on seed crop

***Pinus sylvestris*:** Because the sample stands of *Pinus sylvestris* were distributed primarily in one elevation band (Table 1), it is not possible to make any interpretation of the effects of elevation on seed yields for this species.

***Pinus nigra*:** In *Pinus nigra*, middle zone seed yields were higher than higher zone yields (Table 2).

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4.6. Effect of stand age on seed crop

The seed crops per square meter from different age classes varied considerably varying in all three pine species. Populations of the medium age category generally produced more seeds per square meter than populations of other ages on the same site classes.

In *P. sylvestris*, the 81-100 year-old population generally yielded more seeds than younger (41-60 years) and older (121-140 and 181-200 years) populations (Figure 3).

In *P. brutia* seed yield of 40 year-old populations were generally higher than 20 and 60 year-old populations, both at lower and higher elevation zones. Seed crops of the 60 year-old populations at medium elevations (the optimum range) were the highest (Table 4). Since

populations of other ages were not studied in the middle elevation zone, further examinations were not possible.

Middle zone *P. nigra* populations of the 55-65 year age range exhibited the most abundant seed crops every year (Table 3). Conversely, the seed crops of 120-130 and 140-150 year ranges were, in general, higher than the 55-65 year age category in the higher elevation zone. As in *P. sylvestris*, middle age ranges (80-100 years) of *P. nigra* were not included in this research; they may also give more abundant seed crops.

In summary, populations of middle ages of each tree species may generally produce more seed crops at the same site classes and elevation zones; however, because of differences in life spans of the pine species, the term "middle age" must be accepted as relative.

4.7. Effect of silvicultural treatments

The effects of silvicultural treatments on seed crops were not clear. For *P. sylvestris* populations, the length of the research period was probably insufficient for solid results. In *P. nigra* and *P. brutia*, the most probable cause of unclear results was the application of silvicultural treatments (thinnings) at the beginning of the research period to populations which had also been severely treated in previous years. A negative effect of silvicultural thinnings on seed crops was more clear in *P. nigra* (Table 2, sample plot XI). This negative effect suggests that, during the seed cutting for natural regeneration as well as during intermediate thinnings to seed stands, one must act prudently and not overly reduce the crown cover of the stand. Overcutting may increase the diameter and crown size of the remaining individual trees, but the growing space may not be utilized fully by the fewer number of trees. Seed crops of individual trees may increase to a certain degree (Karlsson and Örlander, 2002), but seed production of the population may remain below the seed crop of the total stand before it was overcut (Sarvas, 1962). In addition, because there are fewer trees after an overcutting, insufficient pollination may also decrease seed quantity and quality. In contrast, a decrease in the number of trees to a certain degree, or an increase in the average stand diameter and crown area, may positively affect the seed productivity as is shown in the case of *P. sylvestris* (Table 1, sample plots VII, VIII, IX).

4.8. Annual periodical dispersal

Seed shedding of both *P. sylvestris* and *P. nigra* occured almost completely during the spring, with maximum shadding in April (Figure 4 a, b). This was followed either by the January-March period or by May in *P. sylvestris*; and it was always followed first by the January-March period and then by May in *P. nigra*. This earlier shedding by black pine could be explained as an adaptation to more droughty ecological conditions, since its natural distribution is always below *P. sylvestris*' elevation belts or in more dry climatic regions. Consequently, more seeds take advantage of early spring precipitation to ensure their future generations (Figure 4 c, d). On the other hand, seed distribution of *P. brutia* occured throughout the year, with maximum dispersal in August and the great majority of seed dispersed within the July-December period (Figure 4 c, d).

In *P. sylvestris* and *P. nigra*, seed dispersal was followed by abundant spring precipitation, which is very important for natural regeneration since all seeds generally germinate by the end of June. *P. brutia*, which is a fire adapted species, showed a dual regeneration strategy: postfire regeneration and regeneration in the absence of fire (in open areas). In addition, *P. brutia* also regenerated both in late autumn-winter (especially in the lower zone) and in spring-depending on the precipitation and temperature.

In summary annual periodic seed dispersal generally occurred during the same time periods each year for each tree species. These times were well correlated with climatic conditions and the geographical distribution of each species to enable it to secure future generations.

4.9. Empty seeds

Empty seed percentages were generally higher in old populations and on poor sites in *P. sylvestris* and *P. nigra* (Tables 1 and 2). There were also indications that empty seed percentages increased slightly during poor seed years and at higher elevations in black pine (Table 2). In *P. brutia*, smaller empty seed percentages could be expected in good seed years (Tables 3 and 4) and in low elevation populations (Table 4).

Insufficient pollination seems to be an important causal factor of the high empty seed percentages in the pine species of Turkey. This phenomenon could occur in older populations, during poor seed years, and at high elevation populations of the tree species.

5. Conclusions

In seed crop studies, a locality or region is generally represented by one or a few sample stands that meet both the scientific and practical requirements. In Turkey, more intensive sample stands were considered in each region to obtain more precise knowledge about the effects of site classes, age categories, silvicultural treatments, and elevation ranges on seed crops. Since the distribution of actual stands did not cover the entire range of conditions to be studied in each locality, some limitations to the design of the seed crop study were inevitable. Results of the research revealed that there were also essential differences among the seed crop of nearby populations of the same site categories and age classes. These differences are probably caused by internal and external factors, including stand structure. A reasonable intensity of sample stands--probably one population for each criteria such as site class, age class, and elevation zone in each locality will generally meet the scientific and practical expectations.

As it is mentioned above (in Chapter 4), the following results were obtained from the seed crop research of the three pine species:

Seed yield was higher in good site classes.

In general, annual fluctations of seed crops were in the same direction in different years in all sample plots for a given species.

Populations of the middle ages of each tree species generally seem to produce more seed crops in the same site classes and elevational zones.

The less the seed weight, the more the seed yield among the three pine species.

Seed crops of the middle elevation zone populations were more abundant than lower and/or upper zone populations. This greater abundance could be attributed to optimum ecological conditions that also lead to optimum flowering and pollination conditions in the middle belt.

Silvicultural treatments (thinnings) slightly increased the seed crop in *P. brutia*. Because the *P. nigra* stands had been severely thinned in years prior to this study and because the research period was insufficiently long in the *P. sylvestris* stands, this effect was not so clear.

Rhythms of seed dispersal generally occured during the same periods within each year for each tree species. These rhythms are well correlated with climatic conditions and the geographic distribution of the species to enable it to secure future generations.

In general, empty seed percentages were positively correlated with poor site classes, poor seed years, very old stands, and higher elevations.

The research results established adequate knowledge on quantity and quality of seed crops, their annual fluctuations, and periodic dispersal within the year for populations of different site classes and age categories in *Pinus sylvestris*, *Pinus nigra* subsp. *pallasiana* and *Pinus brutia* in Turkey. The data obtained have contributed to scientific and practical aspects of seed crop studies together with both natural and artificial regeneration activities of the three pine species.

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Türkiye'de Sarıçam (*Pinus sylvestris*), Anadolu Karaçamı (*Pinus nigra* subsp. *pallasiana*) ve Kızılçamda (*Pinus brutia*) tohum verimi araştırmaları

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Kısa Özet

Bu makalede Sarıçam (*Pinus sylvestris*), Anadolu Karaçamı *(Pinus nigra* subsp. *Pallasiana*) ve Kızılçamda (*Pinus brutia*) tohum veriminin kantite ve kalitesinin, yıllıklara göre ve yıl içindeki periyodik dağılımının, farklı bonitetlerde, yaş kademlerinde ve yükselti basamaklarında, silvikültürel uygulamaların etkileri de dikkate alınarak değerlendirilmiştir. Birim alandaki tohum verimi, aynı yaşlı saf meşcerelerdeki deneme alanlarında, tohum kapanları kullanılarak saptanmıştır.[1]

Araştırma sonuçlarına göre, iyi bonitetlerde tohum verimi yüksek bulunmuş, belirtilen türler için tohum veriminin yıl içindeki değişimi bütün deneme alanlarında genel olarak her yıl aynı doğrultuda gözlemlenmiştir. Her üç türün orta yaş populasyonları, aynı bonitet ve yükseklik zonlarında genellikle daha fazla tohum üretmişlerdir. Hafif tohum ağırlığına sahip çam türlerinin daha fazla sayıda tohum oluşturduğu görülmüştür. Diğer yandan orta zon populasyonlarının, alt ve üst zonlara nazaran daha fazla sayıda tohum verdiği saptanmıştır. Genel olarak boş tohum yüzdeleri, kötü bonitetlerde, fakir tohum yıllarında, yaşlı meşcelelerde ve artan yükseklik ile artmıştır.

Anahtar Kelimeler: Tohum verimi, tohum dağılımı, Sarıçam, Anadolu Karaçamı, Kızılçam.

1. Giriş

Doğal ve yapay gençleştirme çalışmalarında kullanılan birçok yöntemde, türlerin tohum özellikleri önem taşımaktadır. Bununla beraber ileri ıslah tekniklerin uygulanması düşünüldüğünde de türlerin tohum özellikleri üzerinde durulması gerekir. Ülkemizde Kızılçam (4.2 milyon ha), Karaçam (3.3 milyon ha) ve Sarıçam (1.0 milyon ha) toplam orman alanının yaklaşık % 41'ini kaplamaktadırlar (Anonim, 2001; Ürgenç ve Ark., 1993). Belirtilen üç çam türünün tohum özelliklerinin belirlenmesi öncelikli araştırmalar arasında yer almakta olup, bunlara ağaç ıslahı çalışmalarında da öncelik verilmiştir (Koski ve Antola, 1994; Boydak ve Çalıkoğlu, 2000).

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2. Materyal ve Metot

Orman ağaçlarında tohum verimi çalışmalarında önemli ilerlemeler 20. yüzyılın ilk dönemine rastlamaktadır. Tohum kapanları ilk olarak Rus bilim adamları tarafından geliştirilmiş ve zaman içerisinde üzerinde değişik modifikasyonlar yapılarak, birçok ülkede tohum verimi çalışmalarında kullanılmıştır (Morosow, 1928; Sarvas, 1962; Fowells ve Schobert, 1956; Saatçıoğlu, 1970). Tohum kapanları ülkemizde ilk olarak 1970 yılında başlatılan Sarıçamda tohum verimi çalışmasında yer almış ve daha sonra diğer türlerde yapılan çalışmalarda kullanılmıştır (Boydak, 1975; Boydak, 1977; Ürgenç, 1977; Ürgenç ve Ark., 1989; Tosun, 1992; Boydak ve Ark., 2002). Tohum kapanın şematik gösterimi Şekil 1'de görülmektedir.

Birim alandaki tohum sayısı aynı yaşlı, normal kapalılıkta olan saf çam meşcerelerindeki deneme alanlarına yerleştirilen tohum kapanlarında yapılmıştır. Her deneme alanı 0,25 ha (50 X 50 m) alan kaplamaktadır. Sarıçam, Anadolu Karaçamı ve Kızılçamda yapılan tohum verimi çalışmalarında deneme alanlarına meşcere özellikleri de dikkate alınarak 20-30 adet tohum kapanı yerleştirilmiştir (Boydak, 1977; Boydak ve Ark., 2002; Ürgenç, 1977; Ürgenç ve Ark., 1989).

3. Sonuç ve Tartışma

Yapılan araştırmaların bulguları yardımı ile Sarıçam (*Pinus sylvestris*), Anadolu Karaçamı *(Pinus nigra* subsp. *Pallasiana*) ve Kızılçamda (*Pinus brutia*) tohum veriminin kantite ve kalitesinin, yıllar arasında ve yıl içindeki periyodik dağılımının, farklı bonitetlerde, yaş kademlerinde ve yükselti basamaklarında, silvikültürel uygulamaların etkileri de dikkate alınarak incelenmeye çalışılmış ve aşağıdaki sonuçlara ulaşılmıştır:

Tohum verimi iyi bonitetlerde yüksektir.

Genel olarak her üç çam türünde yıllık tohum veriminin değişimi, farklı yıllarda ve bütün deneme alanlarında aynı yöndedir.

Her üç türün orta yaş populasyonları, aynı bonitet ve yükseklik zonlarında genellikle daha fazla tohum üretmişlerdir.

Hafif tohum ağırlığına sahip çam türleri daha fazla sayıda tohum vermektedir.

Orta zon populasyonları, alt ve üst zonlara nazaran daha fazla tohum oluşturmaktadır. Tohum verimindeki bu artış, orta zondaki optimum ekolojik şartların ortaya çıkardığı optimal çiçeklenme ve tozlaşma koşulları ile açıklanabilir.

Aralamaların Kızılçamın tohum verimini az da olsa arttırdığı saptanmıştır. Sarıçamda tohum veriminin saptanmasında çalışma süresinin kısalığı net sonuçların alınması için yetersiz kalmıştır. Karaçamda ise populasyonlara çalışmadan önce, şiddetli silvikültürel işlemler uygulandığından net sonuçlara ulaşılamamıştır.

Sarıçam, Karaçam ve Kızılçamda tohumların yıl içindeki dağılımı, her tür için genellikle aynı döneme rastlamaktadır. Bu tohum dağılım dönemi, türün gelecek

generasyonlarını güvence altına alacak şekilde iklimsel şartlar ve türün coğrafik yayılışı ile uyum içindedir.

Boş tohum yüzdelerinin, genel olarak kötü bonitetlerde, fakir tohum yıllarında, yaşlı meşcelelerde ve yüksekliğin artmasına bağlı olarak arttığı saptanmıştır.

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