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Early evaluation of open pollinated offspring from Polish seedling seed orchards of *Pinus sylvestris* L.

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Abstract: Field trials with open-pollinated progeny of Scots pine were established in 2004 at five climatically different sites of the Polish lowlands. This long-term experiment was aimed to compare the genetic variation and genetic value of the offspring of twenty two seedling seed orchards and two second-generation seed orchard with the offspring of the local so-called economic seed stands, which are the main source of seeds for artificial regeneration of Scots pine in Poland. The early evaluation of quantitative traits of cones, seeds and 1-year-old seedlings attests to remarkable variation between the studied populations. Significant linear correlations were found between some of the studied traits.

Additional key words: Scots pine, open-pollinated progeny, quantitative traits, genetic variation, genetic value.

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Introduction

Scots pine is an Eurosiberian species of the widest range of distribution within the genus *Pinus* (Boratyński, 1993). Genetic variation of that species in the area of Poland has been tested in many provenance and family experiments, for example by Przybylski (1968, 1970), Przybylski and Sztuka (1968), Cierniewski and Przybylski (1978), Giertych (1980, 1988, 1992, 1993, 1995, 1997), Gunia and Żybura (1989), Kowalczyk (1999), Matras (1989, 1999), Rzeźnik (1989, 1990, 1991), Sabor and Stachnik (1990), Orzeł and Sabor (1994), Sygit and Giertych (1995), Bellon (1999), Rożkowski (1999), and Chmura (2000a, 2000b).

The rules of modern methods of selection of Scots pine have been applied in Poland since the 1930s (Giertych 1999). Nowadays obligatory rules were presented lastly by Załęski et al. (2000) and according to them, the main direction of forest tree selection in Poland is population selection supported by individual selection. Among different activities in the field of preservation of forest trees gene resources and forest tree breeding, an establishing 325 ha of Scots pine seedling seed orchards till 2010 has been assumed (Matras 2000).

The next stage of the selection and breeding of Polish forest tree species will be the evaluation of genetic value of the Basic Forest Material (i.e. approved seed stands, plus trees, clonal and seedling seed orchards) through the programme of progeny tests in accordance with the European Union directives (Sabor et al. 2004). The necessity of establishing new criteria of forest tree selection in Poland was also emphasized

by Korczyk (2002) based on the result of his pilot studies.

Clonal and seedling seed orchards derive from phenotypically selected plus trees, which have been propagated vegetatively (by grafting) or generatively (from seeds), respectively. Both of them have advantages and disadvantages described by many authors (Barber and Dorman 1964, Goddard 1964, Johnson 1964, Libby 1964, Toda 1964, Stern and Hattemer 1964, Wright 1964, Zobel and Mc Elwee 1964, Giertych 1975).

The major aim of establishing seedling seed orchards, composed of the generative offspring of selected plus trees, is to produce seeds but they are also perfect for progeny tests and evaluation of the genetic value of maternal plus trees (Kowalczyk 2000). In comparison to clonal seed orchards, seedling seed orchards are much more diverse genetically, as an individual clone represents only one genotype, while a family is a population of genetically diverse individuals representing not only the maternal plus tree but also the genetic pool of many paternal individuals from the approved seed stand (Giertych 1998).

In 1999 the Institute of Dendrology, Polish Academy of Sciences, Kórnik, Poland, undertook research aimed to assess the range of genetic variation of the offspring of clonal and seedling seed orchards and its genetic value in comparison to progeny from so-called economic seed stands. The latter are still the major sources of seeds for artificial regeneration of state-owned forests in Poland.

Two series of experiments were initiated. The methods and early results of the experiment with the offspring of clonal seed orchards, started in 1999, were described in a previous publication (Chmura et al. 2003). In this paper we describe an early evaluation of the experiment with the offspring of seedling seed orchards established in 2004 on the initiative of Prof. Maciej Giertych.

Material and methods

Seedlings

In the experiment we compared twenty two seedling seed orchards of Scots pine from all over Poland (Table 1). In January–March 2002, 15–20 kg of cones have been obtained from each of twenty one seedling seed orchards. Cones were collected from at least 15 trees in each seedling seed orchard representing different families. Seeds were extracted from cones at our laboratory. An exception was the Łąck Forest District, from which we received only extracted seeds collected in this seedling seed orchard in 1998.

For comparison, we used in the experiment also seeds from so-called economic seed stands representing the forest districts where the experimental sites are situated (Table 1). In the Babki Forest District, seeds were collected separately from five local economic seed stands. Some of the seeds from all stands were mixed and marked as the Babki population (no. 3708). Seedlings obtained from those seeds were used on all experimental sites (Table 2). For three out of the five above mentioned economic seed stands in that district, larger numbers of seedlings were obtained, which made possible to test their offspring separately, but only on the experimental site in Babki (Table 1).

The offspring of two second-generation seed orchards – from the Experimental Forest 'Zwierzyniec' of the Institute of Dendrology in Kórnik and from the Susz Forest District – was also used for comparison with the offspring of seedling seed orchards. The offspring of the second-generation seed orchard in Kórnik was planted on all experimental sites, while the offspring of the second-generation seed orchard in Susz only on the experimental site in Babki (because of the small number of the seedlings obtained) (Fig. 1).

From the cones sent by each forest district (from seedling and second-generation seed orchards, and from local economic seed stands), 100 cones were randomly chosen. After seed extraction, 1000 seeds from each district were used to measure the basic qualitative traits (Table 3). In the spring of 2003, the seeds of all Scots pine populations were sown in the nursery of the Jarocin Forest District after treatment with a fungicide (OXAFUN T 75 DS./WS). After a year (on 26th March 2004), 100 seedlings of each population were taken from the nursery in Jarocin to measure some quantitative traits in the laboratory (Table 4).

One-year-old seedlings designated for the experimental site in Wymiarki were taken from the nursery on 31st March. Their roots were protected from drying with a special gel and next the seedlings were transported to the field. The remaining seedlings were taken out of the soil on 5th April and after gelling of the roots they were kept in a cooling chamber at +3°C in the nursery in Jarocin till their transportation to the other experimental sites.

Seedlings of each population were divided into groups of 100 per plastic bag. Each bag was labelled with numbers of the population and of the plot on the given experimental site. Next, every 5 bags were placed in a bigger box with population number and site location. In this way we prepared the set of seedlings of the given population for 5 blocks on each experimental site.

Experimental sites

In the spring of 2004 (Table 2), five experimental sites were established in various climatic zones of the lowlands of Poland – as in a previous experiment con-

cerning the offspring of clonal seed orchards of Scots pine (Chmura et al. 2003).

The soil after clear-cut logging was prepared by ploughing regular furrows in the autumn of 2003 (only in Babki in the spring of 2004). On the plots in Wymiarki, Bytów, Szczebra and Janów Lubelski, 140 plots were distributed randomly (28 populations × 5 blocks), while on the plot in Babki, 160 plots (32 populations × 5 blocks). On each plot, 100 seedlings of the given population (20 seedlings × 5 rows) were

Table 1. Populations which offspring are tested in the experiment

Population number	Regional Directorate of State Forests	Forest District	Forest Range and/or Compt.	Established in	No. of families
Seedling seed orchards					
3683	Łódź	Łąck	Kiernozia	1976	117
3684	Szczecin	Nowogard	Dobra	1976–1989	101
3685	Toruń	Runowo	Chłopigost 2/02	1978	39
3686	Szczecin	Głusko	Moczele	1979	41
3687	Wrocław	Oborniki Śl.	Prusice	1981	36
3688	Piła	Zdrojowa Góra	Wildek	1983–1984	49
3689	Poznań	Syców	Smardze	1984–1994	57
3690	Olsztyn	Zaporowo	Rosiny	1985	65
3691	Lublin	Świdnik	Radawiec 309a	1986	41
3692	Zielona Góra	Lubsko	Jeziory Duże	1988	42
3693	Piła	Jastrowie	Hajda	1988–1990	45
3694	Piła	Sarbia	Cisze	1988–1990	55
3695	Zielona Góra	Szprotawa	Witków	1989	47
3695	Białystok	Krynki	Grzybowszczyzna	1989–1993	56
3697	Zielona Góra	Szprotawa	Jelenin	1990	48
3698	Łódź	Skierniewice	Rylsk	1990	43
3699	Toruń	Runowo	Chłopigost 3/02	1990	47
3700	Zielona Góra	Sulechów	Klenica	1990	49
3701	Szczecin	Bierzwnik	Radachowo	1990	48
3702	Lublin	Świdnik	Radawiec 309b	1992	40
3703	Wrocław	Oleśnica	Strzelce	1993	65
3704	Wrocław	Głogów	Dalków	1995	41
Second-generation seed orchards					
3705	Poznań	ID Kórnik	Las Zwierzyniec	1989–1990	67[4]
3706[1]	Olsztyn	Susz	Przezmark	1998	121[4]
Economic seed stands					
3707	Zielona Góra	Wymiarki	122a	–	–
3708[2]	Poznań	Babki	56h, 10j, 126d, 44c,191g	–	–
3709	Szczecinek	Bytów	nda[5]	–	–
3710	Lublin	Janów Lubelski	160d, 126f, 147	–	–
3711	Białystok	Szczebra	196a, 216c, 132h	–	–
Economic seed stands from Babki Forest District tested separately					
3712[3]	Poznań	Babki	44c	–	–
3713	Poznań	Babki	10j	–	–
3714	Poznań	Babki	126d	–	–
3715	Poznań	Babki	56h	–	–
3716[3]	Poznań	Babki	191g	–	–

[1]Offspring evaluated only in Babki experimental area
[2]Mixture of seeds from 5 economic seed stands of the Babki Forest District
[3]Offspring evaluated only as seeds and 1-year-old seedlings in nursery because of shortage of seedlings for planting in the field
[4]Number of clones
[5]No data available

Table 2. Location of experimental plots, the applied spacing of seedlings, and number of tested populations

Forest district	Forest division	Forest range	Compt.	Longitude	Latitude	Altitude [m]	Spacing [m × m]	No. of tested populations
Babki	Kórnik	Łękno	59w	17°09'	52°09'	80	1.4 × 0.6	32
Bytów	Borzytuchom	Borzytuchom	257k	17°21'	54°11'	160	1.6 × 0.7	28
Wymiarki	Gozdnica	Zabłocie	230c	15°01'	51°24'	155	1.5 × 0.7	28
Janów Lubelski	Janów Lubelski	Pikule	171g	22°20'	50°39'	200	1.5 × 0.6	28
Szczebra	Serwy I	Przewięź	117c	23°05'	53°52'	136	1.5 × 0.7	28

planted; the spacing varied slightly depending on local habits (Table 2).

Individual plots were delimited with four concrete posts, one of them marked with plot number. All experimental sites were located on typical soils suitable for planting Scots pine and surrounded with a buffer zone composed of several rows of pine trees. They were fenced to protect them against damages caused by deer (with the exception of the experiments in Janów Lubelski and Babki). The seedlings were planted within ploughed furrows, into the hole under the dibble.

Wymiarki Forest District (Fig. 1)

On 1st and 2nd April 2004, the seedlings were planted on the experimental site situated in a flat area. The soil is a podzol, composed of shallow deposits of slightly loamy sand overlying loose sand.

Babki Forest District (Fig. 2)

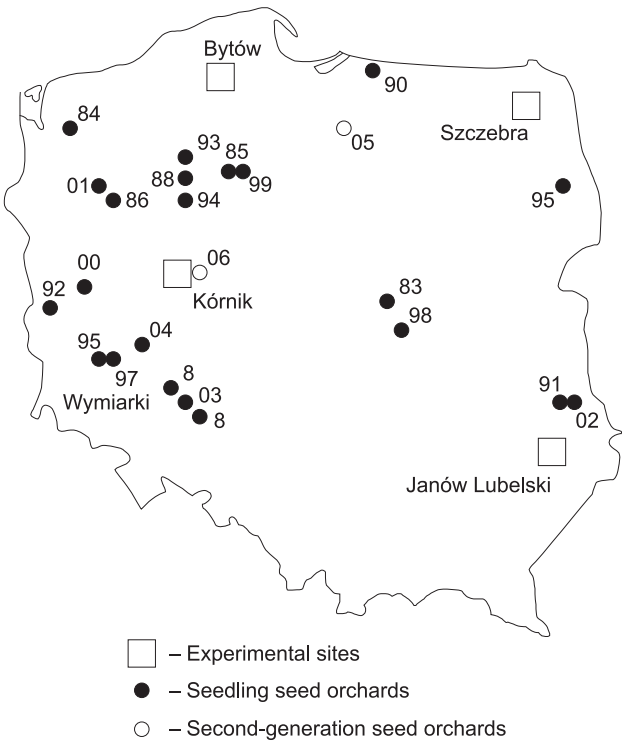


Fig. 1. Location of experimental sites and tested populations (the last two digits of the population numbers given in Table 1 are shown)

Planting was carried out on 6th and 7th April 2004. The area is flat, and the soil is a rusty podzol, composed of shallow deposits of slightly loamy sand overlying loose sand. In some blocks, seedlings of 2 populations from the economic seed stands of Babki were lacking (populations 3713 and 3714). Instead of them, we planted seedlings of population 3694 (on plot 134) or of population 3685 (on plots 62, 96, 101 and 149).

Bytów Forest District (Fig. 3)

After 8-day storage of the seedlings in a cooling chamber, they were planted on 14th and 15th April 2004 on the experimental site with undulated relief, on a rusty podzol composed of shallow deposits of slightly loamy sand overlying loose sand. As a consequence of the shortage of seedlings from Prusice (population 3687), seedlings from Bytów (population 3709) were planted instead on plots 65, 102 and 113.

Janów Lubelski Forest District (Fig. 4)

After 15-day storage of the seedlings in a cooling chamber, they were planted on the experimental plot on 20th and 21st April 2004. Land relief and the soil like in Bytów.

Szczebra Forest District (Fig. 5)

Planting was carried out on 26th and 27th April. In this case, the seedlings were stored in a cooling chamber for 3 weeks. The experimental plot is flat, with a rusty podzol composed of shallow deposits of slightly loamy sand overlying loose sand. To protect it against the pine weevil (*Hylobius abietis* L.), the roots of the seedlings were soaked in a solution of BANCOL 50 WP, just before planting. Because of the shortage of seedlings from Rylsk (population 3698), seedlings from Hajda (population 3693) were planted instead on plot 111. On plot 55, on which some seedlings from Wymiarki (population 3707) were missing, they were supplemented with 20 seedlings from Chłopigost 2/02 (population 3685).

Results and discussion

Measurements of cones and seeds

The population Kiernozia (3683) was not included in the measurements of cones because only extracted seeds were sent from the Łąck Forest District. Values

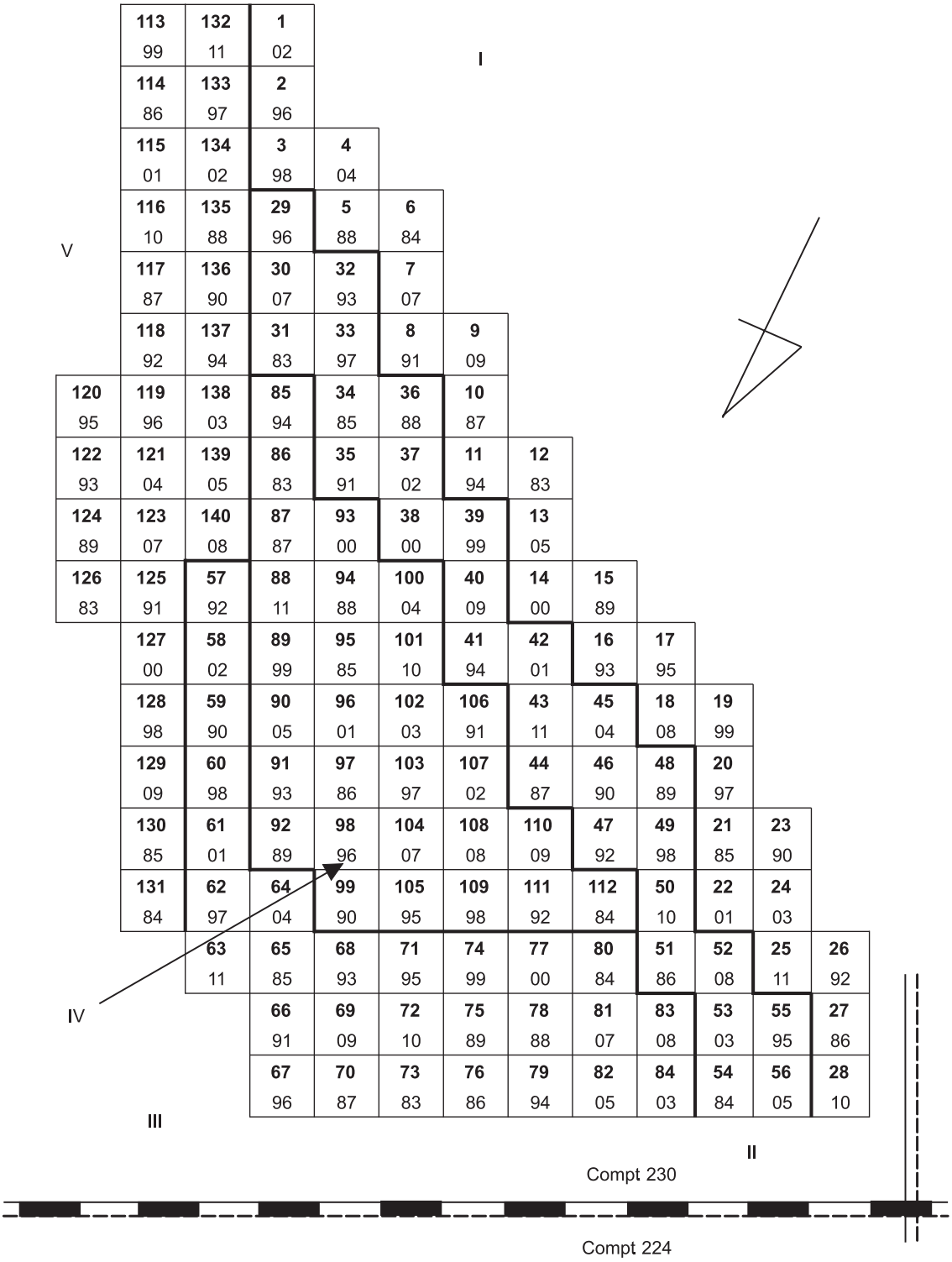
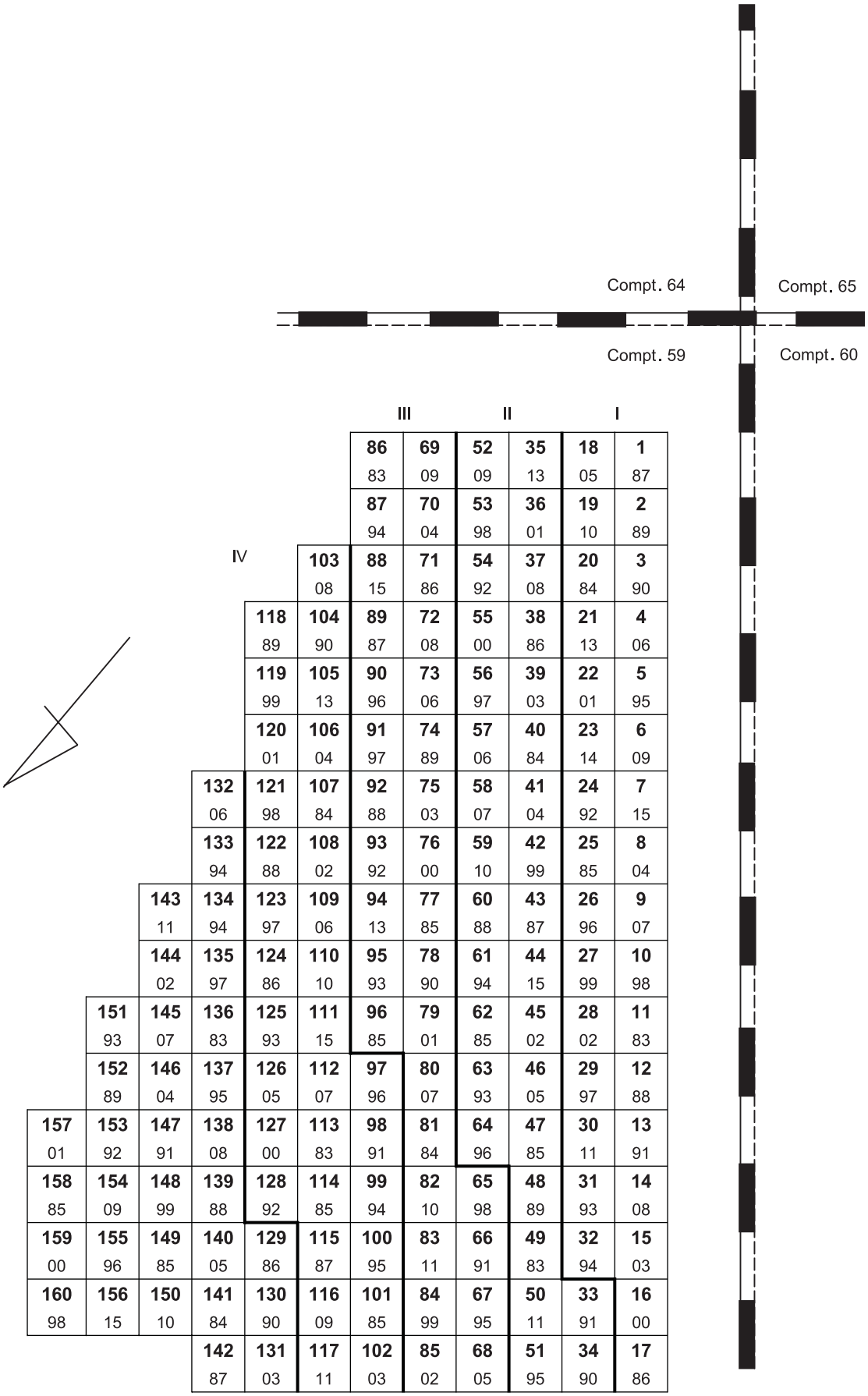


Fig. 2. Lay-out of the experimental site in Wymiarki. Bold digits show plot numbers, while normal digits are the last two digits of the population numbers given in Table 1. Thicker lines show borders between blocks. I–V – block numbers

of the measured quantitative traits of cones and seeds clearly varied between the examined populations (Table 3). The largest and heaviest were the cones from Dalków (3704): average length 52.26 mm, width 25.67 mm and weight 13.87 g. Cones from Smardze (3689) and Dobra (3684) were slightly longer but narrower and much lighter. The Rylsk seedling seed orchard was characterized by the smallest cones: average length 43.35 mm, width 19.88 mm, and weight 7.28 g.

The average 1000-seed weight (full seeds only) was 7.41 g, but higher values were recorded for the seed orchards in Prusice (3687) 9.03 g, Jeziory Duże (3692) 8.50 g, and Smardze (3689) 8.48 g, while the lowest for the seed orchard in Grzybowszczyzna



						86 83	**69** 09	**52** 09	**35** 13	**18** 05	**1** 87
						87 94	**70** 04	**53** 98	**36** 01	**19** 10	**2** 89
					103 08	**88** 15	**71** 86	**54** 92	**37** 08	**20** 84	**3** 90
				118 89	**104** 90	**89** 87	**72** 08	**55** 00	**38** 86	**21** 13	**4** 06
				119 99	**105** 13	**90** 96	**73** 06	**56** 97	**39** 03	**22** 01	**5** 95
				120 01	**106** 04	**91** 97	**74** 89	**57** 06	**40** 84	**23** 14	**6** 09
			132 06	**121** 98	**107** 84	**92** 88	**75** 03	**58** 07	**41** 04	**24** 92	**7** 15
			133 94	**122** 88	**108** 02	**93** 92	**76** 00	**59** 10	**42** 99	**25** 85	**8** 04
		143 11	**134** 94	**123** 97	**109** 06	**94** 13	**77** 85	**60** 88	**43** 87	**26** 96	**9** 07
		144 02	**135** 97	**124** 86	**110** 10	**95** 93	**78** 90	**61** 94	**44** 15	**27** 99	**10** 98
	151 93	**145** 07	**136** 83	**125** 93	**111** 15	**96** 85	**79** 01	**62** 85	**45** 02	**28** 02	**11** 83
	152 89	**146** 04	**137** 95	**126** 05	**112** 07	**97** 96	**80** 07	**63** 93	**46** 05	**29** 97	**12** 88
157 01	**153** 92	**147** 91	**138** 08	**127** 00	**113** 83	**98** 91	**81** 84	**64** 96	**47** 85	**30** 11	**13** 91
158 85	**154** 09	**148** 99	**139** 88	**128** 92	**114** 85	**99** 94	**82** 10	**65** 98	**48** 89	**31** 93	**14** 08
159 00	**155** 96	**149** 85	**140** 05	**129** 86	**115** 87	**100** 95	**83** 11	**66** 91	**49** 83	**32** 94	**15** 03
160 98	**156** 15	**150** 10	**141** 84	**130** 90	**116** 09	**101** 85	**84** 99	**67** 95	**50** 11	**33** 91	**16** 00
			142 87	**131** 03	**117** 11	**102** 03	**85** 02	**68** 05	**51** 95	**34** 90	**17** 86

Fig. 3. Lay-out of the experimental site in Babki. See explanations in Fig. 1

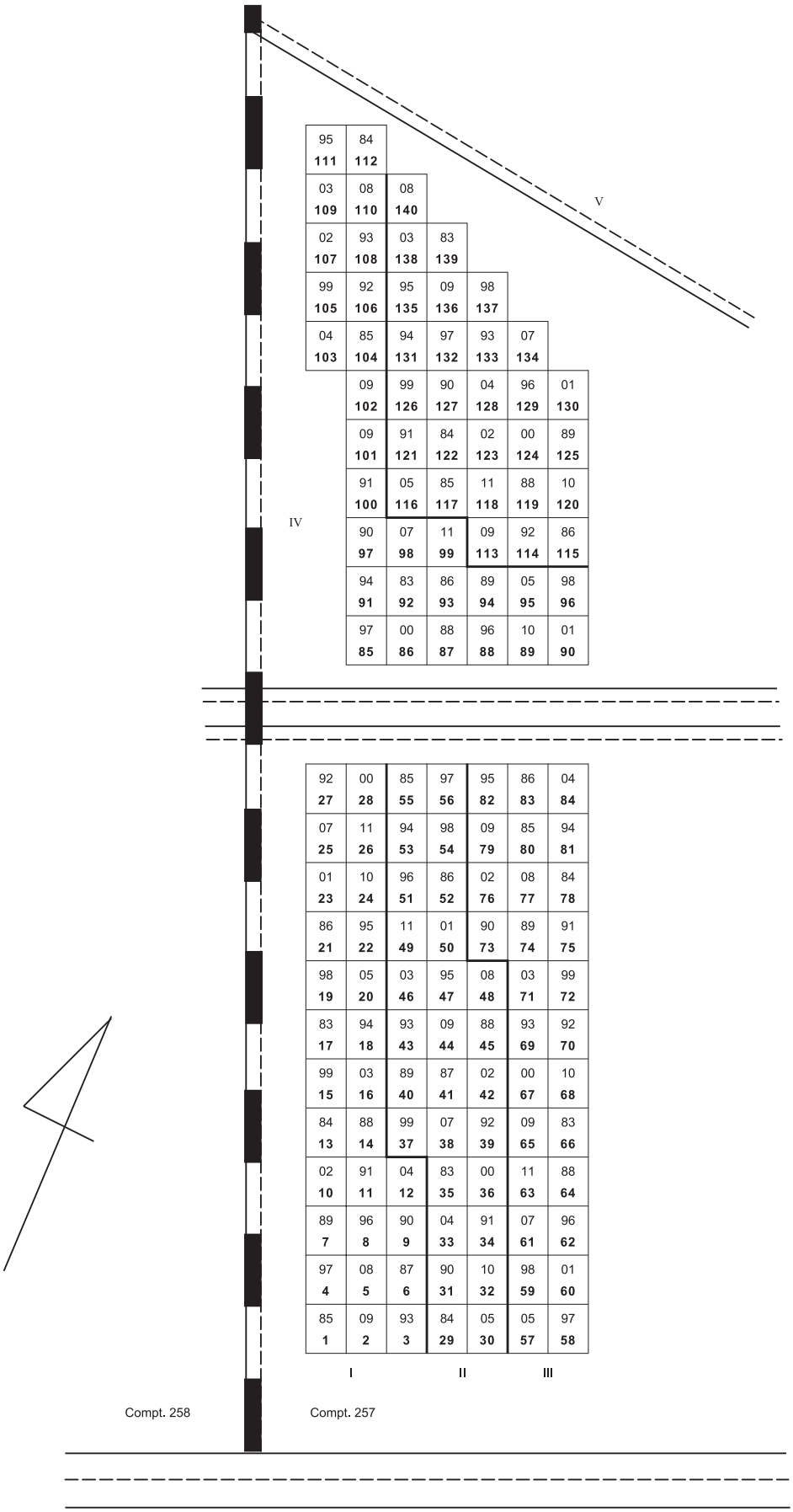


Fig. 4. Lay-out of the experimental site in Bytów. See explanations in Fig. 1

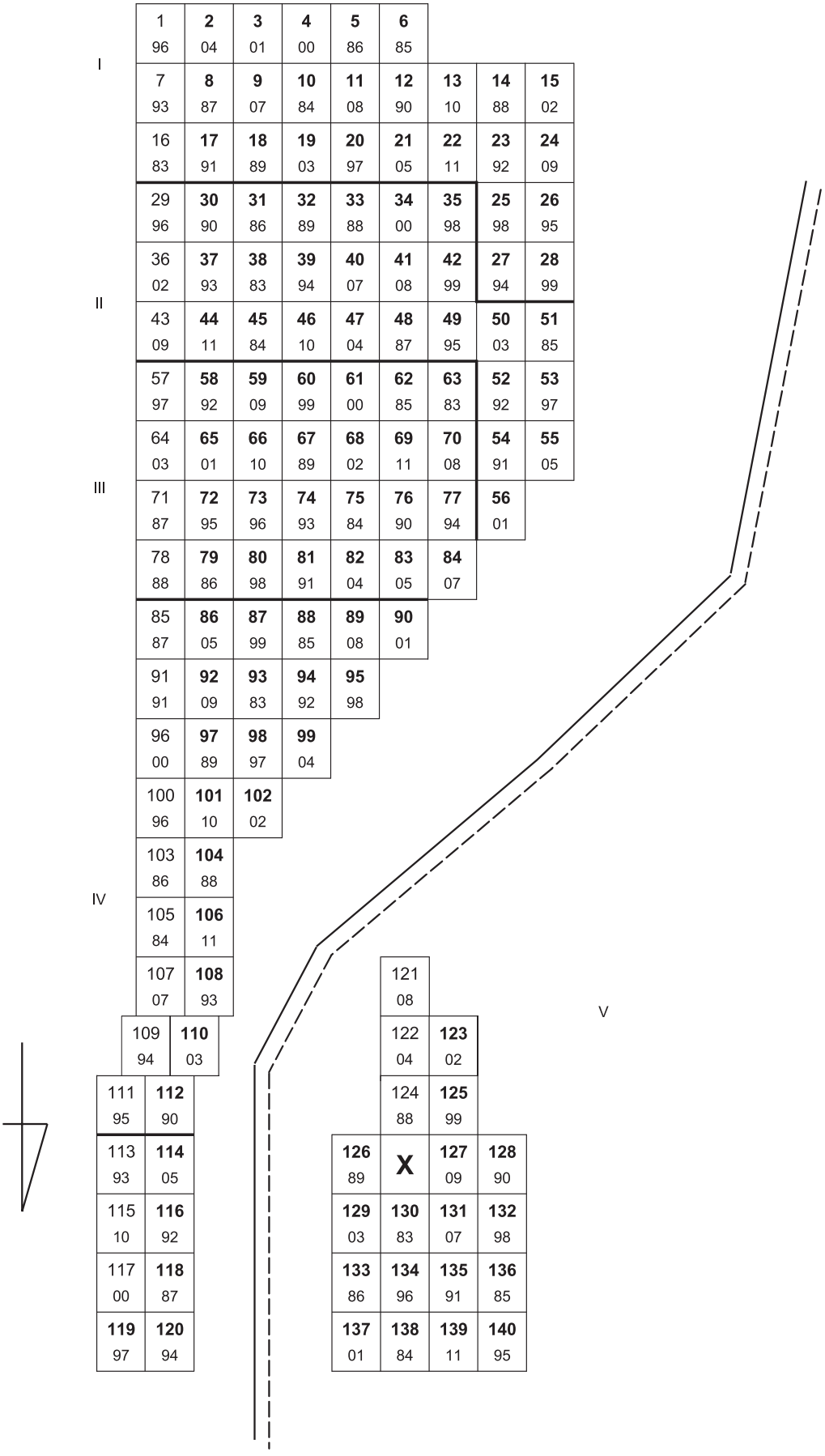
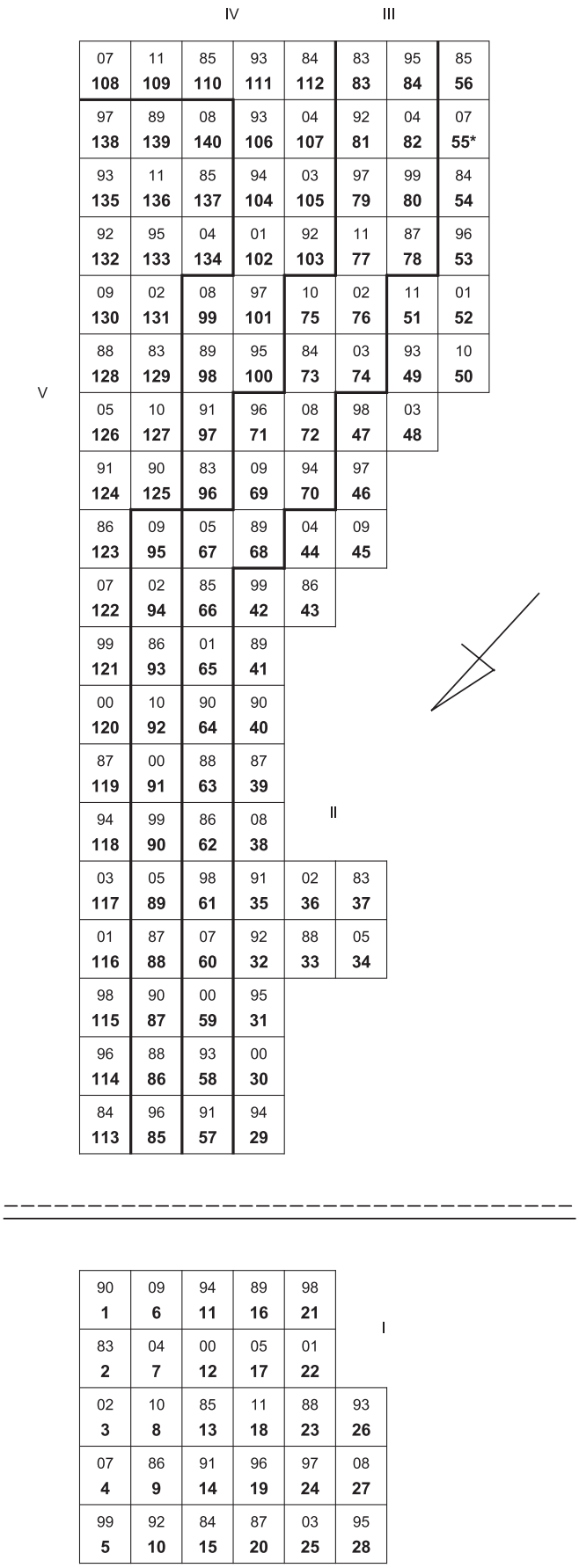


Fig. 5. Lay-out of the experimental site in Janów Lubelski. See explanations in Fig. 1



07 **108**	11 **109**	85 **110**	93 **111**	84 **112**	83 **83**	95 **84**	85 **56**
97 **138**	89 **139**	08 **140**	93 **106**	04 **107**	92 **81**	04 **82**	07 **55***
93 **135**	11 **136**	85 **137**	94 **104**	03 **105**	97 **79**	99 **80**	84 **54**
92 **132**	95 **133**	04 **134**	01 **102**	92 **103**	11 **77**	87 **78**	96 **53**
09 **130**	02 **131**	08 **99**	97 **101**	10 **75**	02 **76**	11 **51**	01 **52**
88 **128**	83 **129**	89 **98**	95 **100**	84 **73**	03 **74**	93 **49**	10 **50**
05 **126**	10 **127**	91 **97**	96 **71**	08 **72**	98 **47**	03 **48**	
91 **124**	90 **125**	83 **96**	09 **69**	94 **70**	97 **46**		
86 **123**	09 **95**	05 **67**	89 **68**	04 **44**	09 **45**		
07 **122**	02 **94**	85 **66**	99 **42**	86 **43**			
99 **121**	86 **93**	01 **65**	89 **41**				
00 **120**	10 **92**	90 **64**	90 **40**				
87 **119**	00 **91**	88 **63**	87 **39**				
94 **118**	99 **90**	86 **62**	08 **38**				
03 **117**	05 **89**	98 **61**	91 **35**	02 **36**	83 **37**		
01 **116**	87 **88**	07 **60**	92 **32**	88 **33**	05 **34**		
98 **115**	90 **87**	00 **59**	95 **31**				
96 **114**	88 **86**	93 **58**	00 **30**				
84 **113**	96 **85**	91 **57**	94 **29**				

90 **1**	09 **6**	94 **11**	89 **16**	98 **21**	
83 **2**	04 **7**	00 **12**	05 **17**	01 **22**	
02 **3**	10 **8**	85 **13**	11 **18**	88 **23**	93 **26**
07 **4**	86 **9**	91 **14**	96 **19**	97 **24**	08 **27**
99 **5**	92 **10**	84 **15**	87 **20**	03 **25**	95 **28**

Fig. 6. Lay-out of the experimental site in Szczebra. See explanations in Fig. 1

Table 3. Results of assessment of quantitative traits of Scots pine cones and seeds from studied seedling seed orchards

Seedling seed orchard	Population number	Mean for one fresh cone			Mean seed weight per cone			1000-seed weight (full only) [g]	Mean seed number per cone			Proportion of full seeds [%]
		length [mm]	width [mm]	weight [g]	full [g]	empty [g]	total [g]		full	empty	total	
Kiernozia*	3683	–	–	–	–	–	–	6.84	–	–	–	–
Dobra	3684	52.38	24.73	11.15	0.205	0.005	0.210	8.40	24.4	3.0	27.5	88.97
Chłopigost 2/02	3685	43.92	20.63	7.10	0.130	0.020	0.151	6.20	21.0	9.5	30.5	68.99
Moczele	3686	47.29	22.43	8.85	0.142	0.009	0.151	6.72	21.1	4.0	25.1	84.05
Prusice	3687	52.08	23.39	10.52	0.123	0.023	0.146	9.03	13.6	9.4	23.1	59.11
Wildek	3688	45.44	21.66	8.05	0.104	0.011	0.116	7.01	14.9	5.9	20.8	71.72
Smardze	3689	52.99	23.34	11.41	0.244	0.009	0.253	8.48	28.7	4.0	32.7	87.85
Rosiny	3690	46.02	22.32	9.17	0.103	0.007	0.110	6.72	15.4	3.6	19.0	80.92
Radawiec 309a	3691	44.90	20.95	7.42	0.116	0.008	0.124	7.53	15.4	4.0	19.4	79.35
Jeziory Duże	3692	50.40	22.39	9.44	0.162	0.012	0.175	8.50	19.1	5.3	24.4	78.38
Hajda	3693	47.26	23.51	7.09	0.141	0.006	0.147	7.44	18.9	2.7	21.6	87.51
Cisze	3694	50.17	22.35	8.38	0.111	0.009	0.120	7.99	13.9	4.2	18.1	76.98
Witków	3695	47.92	20.95	7.86	0.130	0.008	0.138	7.16	18.2	4.0	22.2	81.88
Grzybowszczyzna	3696	45.59	22.14	10.60	0.143	0.005	0.148	5.83	24.4	2.5	26.9	90.89
Jelenin	3697	45.25	21.44	8.21	0.103	0.007	0.110	7.19	14.4	3.4	17.8	80.71
Rylsk	3698	43.35	19.88	7.28	0.142	0.007	0.149	6.81	20.9	3.4	24.3	85.98
Chłopigost 3/02	3699	49.25	23.07	9.38	0.117	0.009	0.126	7.22	16.2	3.8	20.0	81.04
Klenica	3700	49.14	21.47	8.52	0.085	0.004	0.090	7.47	11.4	2.0	13.4	84.81
Radachowo	3701	49.62	23.57	10.23	0.160	0.009	0.169	6.54	24.4	4.8	29.2	83.58
Radawiec 309b	3702	46.65	21.64	8.15	0.083	0.007	0.090	7.95	10.4	3.2	13.6	76.54
Strzelce	3703	48.58	22.58	8.65	0.160	0.009	0.169	7.45	21.5	4.2	25.7	83.82
Dalków 272b	3704	52.26	25.67	13.87	0.220	0.007	0.227	7.56	29.1	3.3	32.4	89.70
General mean		48.12	22.39	9.11	0.139	0.009	0.148	7.37	18.9	4.3	23.2	81.08
Standard deviation		2.91	1.37	1.70	0.042	0.005	0.042	0.79	5.3	1.9	5.5	7.57

*only extracted seeds were available

(3696) 5.83 g. In respect of the mean number of full seeds per cone, two seedling seed orchards were the best: Dalków (3704) 29.09 seeds, and Smardze (3689) 28.71 seeds, while the general mean was 19.16 seeds. The mean proportion of full seeds for the whole experiment was 81.54%. The highest proportions of full seeds were recorded in the populations from the Experimental Forest in Kórnik (3705) 91.18%, Grzybowszczyzna (3696) 90.89%, and Dalkowo (3704) 89.70%, while the lowest in Prusice (3687) 59.11%.

Measurements of seedlings

In the measurements of seedling traits, 34 populations were included, because both seeds and seedlings were available for them (Table 4). All measured traits showed differences between populations. The highest mean leader shoot length was reached by seedlings from the seedling seed orchard in Witkowo (3695) 97.08 mm, Klenica (3700) 92.11 mm, and Dobra (3684) 90.28 mm, and the lowest by seedlings from economic seed stands in Babki (3714) 55.34 mm and Janów Lubelski (3710) 64.71 mm. The general mean was 77.28 mm. Three populations with the highest mean leader shoot length were also characterized by the highest standard deviation: 21.63 mm, 17.32 mm and 18.72 mm, respectively. This attests to a high variation in this trait within those populations.

The highest fresh weight of 100 roots was recorded in seedlings from Jelenin (3697) 55.6 g, and the lowest in those from Chłopigost 3/02 (3699) 16.4 g. The fresh weight of 100 shoots was the highest in the population Hajda (3693) 170.4 g, and the lowest in the population Chłopigost 3/02 (3699) 50.2 g (Table 4).

Analysis of correlation

Mean values of the measurements of cones, seeds, and seedlings for twenty one seedling seed orchards were subjected to an analysis of Pearson's linear correlation. The population Kiernozia (3683) was excluded from the analysis because its cones were not available. Some of the analysed traits are correlated at the significance level of $p = 0.05$ (Table 5). It is noteworthy that 1000-seed weight is significantly and positively correlated with cone length ($r = 0.71$) and less significantly with cone width ($r = 0.39$). This result confirms

Table 4. Results of assessment of quantitative traits of 1-year-old seedlings

Population number	Shoot length [mm]				Fresh weight (per 100 seedlings) [g]		Dry weight (per 100 seedlings) [g]		
	min.	max.	mean	standard deviation	roots	shoots	roots	shoots	needles
Seedling seed orchards									
3683	35	105	73.09	14.78	19.6	70.5	6.3	6.8	14.1
3684	50	140	90.28	18.72	52.5	135.6	19.3	18.0	35.0
3685	40	110	71.94	15.24	33.5	85.3	12.0	9.4	20.4
3686	50	110	81.55	13.44	24.0	94.4	9.1	9.4	21.0
3687	26	120	71.09	16.60	47.1	104.4	19.8	14.2	39.1
3688	21	140	82.56	18.86	29.6	96.8	9.7	9.2	21.0
3689	35	105	71.85	15.21	36.5	90.0	12.8	9.0	23.0
3690	45	125	83.86	16.49	33.9	103.7	13.0	12.4	25.3
3691	55	125	87.81	14.99	19.0	88.0	8.0	10.1	21.0
3692	45	130	88.39	18.06	18.4	76.1	7.2	9.3	17.3
3693	45	130	74.96	18.79	46.7	170.4	17.1	17.3	39.7
3694	38	90	61.51	12.19	26.2	63.2	8.8	10.5	27.5
3695	32	145	97.08	21.63	34.3	129.4	14.5	18.0	35.0
3696	40	125	77.22	15.66	37.2	82.5	16.0	13.6	33.4
3697	45	140	82.55	20.13	55.6	144.6	20.8	18.3	42.0
3698	45	115	73.89	15.10	17.7	61.2	6.2	6.2	13.0
3699	45	95	65.77	12.50	16.4	50.2	6.0	5.6	11.8
3700	40	130	92.11	17.32	19.2	84.3	7.3	9.1	16.5
3701	40	120	70.26	14.47	40.5	102.6	12.6	10.0	23.2
3702	47	110	83.80	13.61	32.8	124.0	12.1	12.5	30.0
3703	45	130	82.11	17.71	44.6	115.7	15.7	12.4	26.2
3704	40	145	86.64	19.32	30.1	98.4	11.4	12.3	23.3
Second-generation seed orchards									
3705	35	105	66.14	12.26	10.9	43.1	3.5	4.1	9.0
3706	45	150	76.71	17.57	36.6	132.6	14.3	14.3	33.0
Economic seed stands									
3707	45	108	70.89	14.22	19.4	51.0	6.6	5.2	11.3
3708	50	160	89.90	23.22	44.3	138.2	17.3	18.0	35.5
3709	35	150	87.38	20.60	36.7	109.4	17.0	18.8	38.5
3710	38	100	64.71	14.17	23.3	67.3	8.8	10.6	16.0
3711	46	110	76.44	13.90	29.9	62.2	10.1	7.0	14.0
Economic seed stands from Babki Forest District tested separately									
3712	40	95	70.38	13.55	20.0	77.3	20.0	9.0	8.8
3713	40	110	79.36	13.06	30.0	106.5	9.1	9.8	23.0
3714	23	88	55.34	12.62	26.6	79.0	8.1	7.3	18.4
3715	40	115	70.72	13.75	36.4	102.2	12.8	10.0	25.0
3716	40	105	69.08	14.72	22.1	107.2	33.4	13.9	13.2
General mean	–	–	77.28	16.01	30.58	94.14	11.5	11.1	24.2

Staszkiewicz's (1993) conclusion that heavier seeds are born in larger cones. In the present study, 1000-seed weight is not significantly correlated with seedling shoot length (r = 0.07), which contrasts with results of Oleksyn and Rachwał (1994). The mean number of full seeds per cone is significantly correlated with cone width (r = 0.50) and cone weight (r = 0.61). Besides, 1000-seed weight (full seeds only) is positively and significantly correlated with the proportion of full seeds (r = 0.48) (Table 5).

The fresh weight of shoots, roots and needles were significantly and positively correlated with their dry weight, but this is quite obvious. However, significant positive correlations were also found between maximum shoot length and dry weight of 100 shoots (r = 0.60) and of 100 roots (r = 0.42). Close to signif-

Table 5. Matrix of Pearson's coefficients of linear correlation between quantitative traits of Scots pine cones, seeds and seedlings (N = 21; bold values significant at p < 0.05)

No.	Trait	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Cone length																	
2	Cone width	**0.80**																
3	Cone fresh weight	**0.74**	**0.82**															
4	Weight of full seeds per cone	**0.60**	**0.63**	**0.69**														
5	Weight of all seeds per cone	**0.60**	**0.62**	**0.69**	**0.99**													
6	1000-seed weight (full only)	**0.71**	0.39	0.29	0.26	0.28												
7	Number of full seeds per cone	0.33	**0.50**	**0.61**	**0.92**	**0.90**	–0.14											
8	Number of all seeds per cone	0.32	**0.44**	**0.56**	**0.86**	**0.89**	–0.09	**0.94**										
9	Proportion of full seeds	0.10	0.27	0.30	**0.48**	0.39	–0.25	**0.57**	0.25									
10	Mean shoot length	–0.04	–0.08	0.01	–0.01	–0.05	0.07	–0.07	–0.18	0.24								
11	Fresh weight of 100 seedling roots	0.18	0.36	0.19	0.21	0.22	0.13	0.18	0.21	–0.01	0.00							
12	Fresh weight of 100 seedling shoots	0.02	0.23	–0.08	0.04	0.02	0.13	–0.02	–0.07	0.12	0.39	**0.78**						
13	Dry weight of needles	0.11	0.22	0.05	–0.02	–0.02	0.20	–0.08	–0.08	–0.07	0.11	**0.85**	**0.79**					
14	Dry weight of 100 seedling shoots	0.11	0.24	0.07	0.05	0.03	0.16	–0.01	–0.06	0.10	0.40	**0.80**	**0.86**	**0.93**				
15	Dry weight of 100 seedling roots	0.17	0.32	0.20	0.17	0.18	0.15	0.13	0.16	–0.05	0.09	**0.97**	**0.77**	**0.91**	**0.86**			
16	Minimum shoot length	–0.19	–0.02	–0.14	0.03	–0.02	–0.10	0.06	–0.11	**0.46**	0.17	–0.13	0.06	–0.14	–0.01	– 0.14		
17	Maximum shoot length	–0.01	0.14	0.16	0.14	0.11	–0.02	0.13	0.07	0.20	**0.78**	0.38	**0.58**	0.37	**0.60**	**0.42**	–0.12	
18	Latitude	–0.18	0.17	–0.04	–0.11	–0.11	**–0.50**	0.09	0.08	0.09	–0.27	0.09	0.00	–0.02	–0.01	0.03	0.03	–0.14
19	Longitude	**–0.51**	–0.39	–0.18	–0.25	–0.26	–0.29	–0.12	–0.18	0.06	–0.10	–0.21	–0.22	–0.07	–0.18	–0.13	0.27	–0.27

icance level 0.05 was also a correlation between maximum shoot length and fresh weight of roots (r = 0.38) and dry weight of needles (r = 0.37) (Table 5). This suggests that an extensive photosynthetic apparatus and root system (good supply of water and mineral salts) create conditions of maximum utilization of the genetic potential for seedling growth.

Conclusions

The early evaluation of quantitative traits of cones, seeds and seedlings revealed remarkable differences between and within the studied populations of Scots pine. On the basis of these preliminary results, it is however too early to draw any definite conclusions about differences in genetic value between the tested offspring of seedling seed orchards and economic seed stands, and further studies of their future variation with age will be continued.

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