Acta Sci. Pol.
Silv. Colendar. Rat. Ind. Lignar. 11(4) 2012, 45-55

TECHNICAL AND TECHNOLOGICAL PROGRESS IN POLISH FOREST NURSERIES

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Abstract. This article presents new technological and technical solutions for forest nursery, which were developed recently in Department of Forestry Mechanization at Agricultural University in Krakow and implemented in forest nursery. Fertilizer dispensers equipped with mechanism to mix, loosen, and initial soil thickening were made, in order to enrich the ground with mycorrhizal fungi, fertilization and presowing preparation of soil. Thick seeds spot seeding section of Agricola Italiana type PK seeder was modified in order to use in spot seeding, so now it can sow thick seeds like beech or fir and tiny seeds in double rows which make it a universal seeder to sowing forest trees seeds. Sections, up to 5, mounted on construction can spot sow seed perches in field conditions. In order to use in corridor, sowing field seeder arm was modified by extending it, so it was possible to mount sideways seeding units and tractor can be driven next to corridor. Electrical tool holder was constructed for spot seeding under cover, to which you can mount equipment for soil preparation (sowing fertilizer, mycorrhizal biopreparate dosage, loosing and rolling ground), spot seeder sowing sections or constructed saddle for performing weeding.

Key words: soil preparations in nurseries, spot seeding, fertilizer dispenser, cultivation in corridors, forest nursery

INTRODUCTION

In Poland around 90% of renewable forest surfaces are artificial which requires well developed forest nursery that will be able to provide supply of saplings. Overall production of saplings in Poland in 2012 was 829 mln units where 8% is specialized production (containerized), and the rest is conducted in field conditions. 38.8% of it are saplings of coniferous trees, 52.5% saplings of deciduous trees and around 1% are shrubs [Berft 2011]. That kind of saplings production requires lots of labour and involvement of significant resources necessary for its implementation. Because of that almost every nursery of National Forests has higher costs than revenues from selling of saplings. That points onto need of rationalization of the production.

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On the 22 April 2009 general director of National Forests introduced the decree no. 27 which implements forest nursery development program in National Forest organizational units for years 2009-2015. This program assumes better nurseries adaptation to changing breeding tasks and also foreseen constant need of upgrading methods, production technology and cost optimization. Those tasks are implemented by:

1. Adoption of the principle of nursery production self-sufficiency as part of National Forest Regional Directorate.
2. Reducing excess of nursery production surface.
3. Promoting the development of modern, intensive nursery production methods.

The last point of the program is the work of Department of Forestry Mechanization at University of Agriculture in Krakow. This work involve mainly developing of new seedling production technology for forest nursery and appropriate constructions for those technologies allowing to obtain first-class quality seedling and production mechanization.

In front of modern forest nursery, hard task of producing high quality seedling is placed. Those seedlings are supposed to have long life so after seeding no amendments will be necessary and crop care will be cheaper (shorter period). To perform seeds sowing, preparation of sowing surface, fertilization, is necessary and when producing mycorrhizal seedlings, introduction of biopreparate to soil and sowing. Spring pre-sowing soil cultivation usually involves creating of seed perch with help of perches furrower and seedbed preparation which includes fertilization, mixing biopreparate with soil, loosening, levelling of the seeding surface and initial increase of seeding ground density.

NURSERY SUBSTRATES DISPENSER

In seedling production technology there is need for balanced mix of fertilizer with soil often enriched with compost, peat or peat containing mycorrhizal fungi. This treatment can be performed by using dispenser constructed in Department of Forestry Mechanization at Agricultural University in Krakow and is produced by Centre for Forestry Techniques in Jarocin (Fig. 1).

Fig. 1. SRS Fertilizer dispenser at work in nursery
Rys. 1. Dozownik substratu – model SRS podczas pracy w szkółce

At the bottom of loading box with capacity of 3 m^3, SRS Fertilizer dispenser has floor conveyor which allows to dispense up to 3 m^3 of substrate per ar. The dispenser placed in the front part of the machine evenly spreads the substrate dosed at the set amount. Later it is mixed with the top layer of soil by the cultivator placed in the rear of the dispenser and thickened with a string shaft. Floor conveyor drive is made of gearing and hydraulic motor which allows a wide range of substrate regulation. Fertilizer is particularly useful for dispensing substrate with micorrhizal fungi which is sensitive to drying and requires mixing with soil throughout the entire working depth right after dispensing on surface. This machine has allowed developing of new miccorhizal seedlings production technology. It allows to use worn out substrate which was used for production of micorrhizal seedling in corridors instead of micorrhizal biopreparate in open nurseries [Ektomikoryzy... 2007]. Soil prepared in this way is ready for seed spot seedling (Fig. 2). The cultivator is connected with a substrate dispenser with three-point suspension system which allows each machine to work independently.

Fig. 2. Soil prepared for sowing
Rys. 2. Gleba przygotowana do siewu

A similar machine for biopreparate dispensing during controlled micorrhization process was designed for usage in corridors. It also has granular fertilizer seeder, biopreparate dispenser, cultivator and string shaft. This machine is mounted sideways relative to the tractor on the same seeder frame – in place of sowing sections (Fig. 3).

Floor conveyor drive of biopreparate dispenser and fertilizer seeder is acquired by seeder drive wheel through gearbox which gives large biopreparate dose regulation possibilities and guarantees its stability. Thanks to separate setting regulation of granular fertilizer dispenser it is possible to independently regulate the amount of fertilizer seeded and biopreparate dispersion. The cultivator is powered by a hydraulic drive powered by external tractor hydraulics. It is responsible for mixing dispensed biopreparate and granular fertilizer with soil, proper loosening and thickening by string shaft. On the constructed dispenser dispensing trial of granular fertilizer Osmocote was conducted, with extended period of decomposition. Its parameters are shown in Table 1.

Fig. 3. Dispenser during work in corridors
Rys. 3. Dozownik podczas pracy w korytach

Table 1. Fertilizer Osmocote size structure (1 dcm^3 of fertilizer weighed 1158 g)
Tabela 1. Struktura wymiarowa nawozu Osmocote (masa 1 dcm^3 nawozu wynosiła 1158 g)

Specification Wyszczególnienie	Granulation, mm Granulacja, mm	Fraction, % Frakcje, %
1	< 2.0	9.1
2	2.0-29	19.5
3	3.0-3.9	62.4
4	> 9.0	9.0

Fertilizer dispenser has the dosing unit regulated with lever which can influence the amount of dispensed fertilizer (Fig. 4).

Measurements of fertilizer dosing with different regulation lever position were conducted for 10 dispenser drive shaft revolutions. Results are shown in Table 2.

As shown in Table 2 stable dosing is when regulation lever is at position 0-7 where dosage variability does not exceed 6%. At positions –1 to –3 dosing is clearly disrupted and at position –3 dosing unit is almost closed. It can be concluded that regulation lever should be used in the same way as in grain seeders which means a possibility of applying adjustments of dosing unit to size of seeded granules. Dosing itself should be regulated by change of drive shaft rotations on certain distance by gear change in the gear box. Position "0" is assumed as proper lever setting for fertilizer with granulation presented in table 1 and fertilizer seeding dosages were calculated for it. Table 3 shows fertilizer dosing range which is really wide and is 55-178 $g \cdot m^{-2}$ which allows seeding of 156-509 m^2 corridors surface with one filling of the tank.

Fig. 4. Dispense outlet regulating lever with position scale
Rys. 4. Dozownik z widoczną skalą położenia dźwigni regulującej wielkość wylotu

Table 2. Fertilizer dosing for 10 shaft drive revolutions, g
Tabela 2. Dawkowanie nawozu dla 10 obrotów wałka napędowego, g

Lever position Położenie dźwigni dozownika	Container number Numer pojemnika				Container avarage Średnia z pojemnika g	Coefficient of variation Współczynnik zmienności %	Seeding dosage Dawka wysiewu g
	1	2	3	4			
7	222	241	241	229	233.3	4.0	933
5	223	240	241	227	232.8	3.9	931
2	217	234	237	224	228.0	4.0	912
1	215	234	237	223	227.3	4.5	909
0	210	233	237	221	225.3	5.4	901
–1	182	215	215	214	206.5	7.9	826
–2	10	11	30	53	26.0	77.8	104
–3	1	1	2	5	2.3	82.3	9

Similar research was conducted for substrate dispenser and its results are shown in Table 4. It shows possibility to adjust the dose on m^2 of corridor surface in range 2.7-22.1 ($dm^3 \cdot m^{-2}$), and applied cleanly surface during one filling of the tank with recommended dose 8 ($dm^3 \cdot m^{-2}$) is around 0.2 ar.

The described dispenser is particularly important for forest practice, because the method of soil preparation used so far inevitably involves local over-compaction of substrate, and therefore with very different plants growth conditions. Depressions

Table 3. Fertilizer dosage on area unit ($g \cdot m^{-2}$) for each gear and dispenser working width which is 0.5 m. Position "0" of dosing unit regulating lever. Area sown with one filling of the tank with fertilizer Osmocote (24 dcm^3 – 27.8 kg) in dependency of used dosage

Tabela 3. Dawka nawozu na jednostkę powierzchni ($g \cdot m^{-2}$) dla poszczególnych biegów I szerokości roboczej dozownika 0,5 m oraz pozycji „0" położenia dźwigni regulacyjnej zespołu wysiewającego. I powierzchnia obsiana przy jednym napełnieniu zbiornika nawozem Osmocote (24 dcm^3 – 27,8 kg) w zależności od stosowanej dawki

Gear Przełożenie	Drive shaft rotations during 20 m road Obroty wału napędowego dla drogi 20 m		Dispensed fertilizer Masa wysianego nawozu g	Fertilizer dosage Dawka nawozu $g \cdot m^{-2}$	Fertilized area with one filling of the tank Powierzchnia nawieziona przy jednym napełnieniu zbiornika m^2
	°	obr			
1	4 120°	11.44	1 040	104	267
2	4 600°	12.78	1 162	116	239
3	5 240°	14.56	1 324	132	210
4	5 960°	16.56	1 505	151	184
5	7 040°	19.56	1 778	178	156
1a	2 160°	6.00	545	55	509
2a	2 400°	6.67	606	61	458
3a	2 720°	7.56	687	69	404
4a	3 080°	8.56	778	78	357
5a	3 680°	10.22	929	93	299

Table 4. Surface performance of the substrate seeder for entire volume of the tank (185 dcm^3) for maximal and minimal opening of dosing unit, $dm^3 \cdot m^{-2}$

Tabela 4. Wydajność powierzchniowa siewnika substratu dla całej objętości zbiornika (185 dcm^3) przy maksymalnym i minimalnym otwarciu zasuwy, $dm^3 \cdot m^{-2}$

Gear Przełożenie	Maximal opening of dosing unit Maksymalne otwarcie zasuwy		Minimal opening of dosing unit Minimalne otwarcie zasuwy	
	dosage dawka $dm^3 \cdot m^{-2}$	fertilized area nawieziona powierzchnia m^2	dosage dawka $dm^3 \cdot m^{-2}$	fertilized area nawieziona powierzchnia m^2
1	2	3	4	5
1	12.2	14.4	5.17	34.0
2	13.7	12.9	5.8	30.5
3	15.6	11.3	6.6	26.8
4	17.7	10.0	7.5	23.5
5	22.1	8.0	9.4	18.9
1a	6.4	27.5	2.7	64.9

Table 4 – cont. / Tabela 4 – cd.

1	2	3	4	5
2a	7.1	24.7	3.0	58.4
3a	8.1	21.8	3.4	51.6
4a	9.3	19.0	3.9	44.9
5a	10.9	16.1	4.6	38.1

Fig. 5. Preparation of soil in corridors using diesel cultivator
Rys. 5. Stosowane w praktyce przygotowanie gleby w korytach za pomocą glebogryzarki spalinowej

caused by shoes shown on picture 5 (Fig. 5) are later seized with rakes which only leads to additional deterioration of fertilizer uniformity (in places of depressions will be more fertilizer) and does not eliminate local compaction of the substrate.

DISPENSER OF FERTILIZER AND SUBSTRATE FOR WORK UNDER COVERS

A machine with similar functionality was constructed with intention to use under cover. In that case an electric drive vehicle was constructed, which moves over seeding perch thanks to proper rail placed on sidewalks between perches (Fig. 6).

This solution releases the operator from driving the machine and guarantees tool-holder trajectory repeatability in consecutive runs. The toolholder is equipped with a tool frame operated slidably by a screw mechanism. A different kind of machines and tools can be mounted to this frame. Thanks to such a construction the dispenser working width can be much smaller than seeding perch width (which was 0.2 m in this case) and

Fig. 6. Substrate dispenser during work in foil tent
Rys. 6. Dozownik substratu podczas pracy w namiocie foliowym

preparation of the whole seeding perch can be made in few rides. This allowed to significantly reduce the weight of the dispenser and its requirements for drive power. A lower efficiency of the machine acquired through that is irrelevant, because soil preparation process is significantly sped up compared to the existing manual preparation, and machine itself is used only few days in a season.

The dispenser is equipped with two tanks, one bigger designed from biopreparate dosing and smaller second one is used for granulate fertilizer seeding. Dosages of biopreparate and fertilizer are adjusted independently. Dispenser work is similar as in corridors. Dosing unit is dosing biopreparate and fertilizer sowing it in front of the machine. Afterwards, the cultivator mounted on the machine mixes those components with substrate of 10 cm thickness. String shaft is placed behind the cultivator and it kneads too much loosened soil and stabilizes working depth of the cultivator. Engine with power 0.5 kW was used as cultivator drive and it allowed continuously variable working speed.

SEEDS SPOT SOWING

Row sowing machines are traditionaly used in field forest nursery and in corridors and under cover; it is done manualy and vertical and horizontal placements are random. In manual seeding a proper thickness of the seeds cover is big problem. Seeds are covered using harrowing, raking or covered with sand which leads to situation where some seeds are on surface uncovered and some are covered by too thick layer. In both cases seeds have problems with germination; they are irregular and their shape is highly below laboratory germination ability [Tylek and Walczyk 2011]. Consequence of that is irregular germination of seeds and usage of higher seeds sowing norm. The next problem with that technique is uneven use of nursery sowing area. Manual sowing requires

a sower with a large experience because seeds placement on surface depends on his skill and achieving similar sowing distances between seeds is almost impossible. New sowing technology was developed for reasons described above and existing spot sowing seeder were adjusted specially for forest trees seeds spot sowing.

Spot sowing seeder allows not only proper seeds sowing and their placement in rows at a set up distance between them but also owns a machine which guarantees optimal sowing depth and pressing of sown seed to soil. Each seedling is provided with same access to light and nutrients on their own living space. Seedlings roots are not concrescent with each other which limits damage while pulling them out of the ground. Spot sowing requires careful soil preparation, good maintenance and usage of high quality, pollution-free seeds. In case of seeds with lower germination ability, distance between seeds in rows should be properly lowered so that the required amount of vital seeds per area unit would be fulfilled. In spot sowing norm should not be given traditionaly in $g \cdot ar^{-1}$ per area unit of sowing surface but in amount of seeds sown on distance of one meter or m^2. The results of studies on spot sowing were presented in many scientific publications [Tylek and Walczyk 2008, 2011, Walczyk 2008, 2009, 2010].

Recently, thick seeds spot seeding section of Agricola Italiana type PK seeder was modified in order to use in spot seeding, so now it can sow either thick or tiny seeds. This solution allows spot seeding of all forest tree seeds both thick and tiny while using the same seeder sowing section (Fig. 7).

Fig. 7. Usage of PK type seeder to spot sowing in foil tent
Rys. 7. Siew punktowy siewnikiem typu PK w namiocie foliowym

Sowing sections of this seeder can be used either for sowing in fields, corridors or glasshouses. View of seedlings obtained through spot sowing, are presented on picture (Fig. 8).

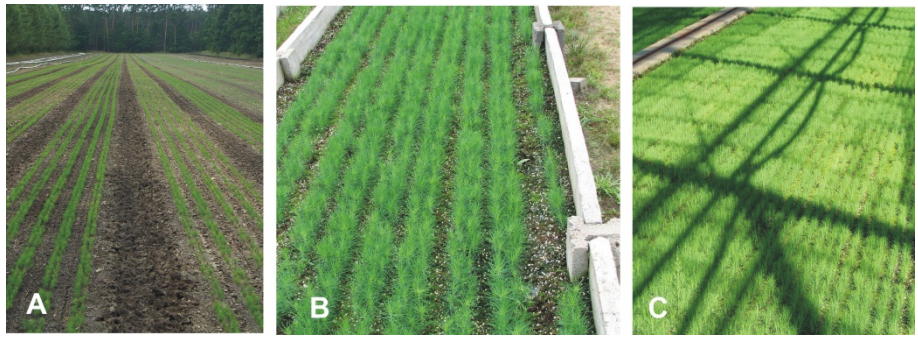

Fig. 8. View of seedling obtained by spot sowing: A – in ground nursery, B – in the corridors, C – in the greenhouse
Rys. 8. Widok siewek uzyskanych z siewu punktowego: A – w szkółce gruntowej, B – w korytach, C – w szklarni

CONCLUSIONS

1. Machines designed and implemented into production fill the gap in mechanization of presowing of preparations of soil for all types of cultivation in forest nurseries.

2. Fertilizer dispenser during one ride loosens the soil, dose and mix biopreparat with ground and preliminary, evenly thickens them preparing for sowing.

3. Spot sowing eliminates imprecise and burdensome manual work, speeds up sowing process, allows precise sowing of single seeds, guarantees even vertical and horizontal distribution of seeds which ensure every plant similar space needed for growth.

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POSTĘP TECHNICZNY I TECHNOLOGICZNY W SZKÓŁKARSTWIE POLSKIM

Streszczenie. W pracy przedstawiono nowe rozwiązania technologiczne i techniczne dla szkółkarstwa leśnego, które w ostatnim czasie zostały opracowane w Katedrze Mechanizacji Prac Leśnych Uniwersytetu Rolniczego w Krakowie i wprowadzone do praktyki leśnej. W celu wzbogacenia podłoży w grzyby mikoryzowe oraz polepszenia nawożenia i przedsiewnego przygotowania gleby skonstruowano dozowniki nawozów oraz biopreparatu wyposażone w mechanizm do mieszania, spulchniania i wstępnego zagęszczania gleby. Do siewu punktowego zmodyfikowano sekcje siewnika punktowego firmy Agricola Italiana typ PK do nasion grubych. Mogą więc one wysiewać dwurzędowo zarówno nasiona ciężkie (buk, jodła), jak i lekkie, dzięki czemu siewnik stał się uniwersalny do wysiewu nasion drzew leśnych. Sekcje wysiewające, mocowane do 5 sztuk na ramie, mogą obsiewać punktowo grzędy siewne w warunkach polowych. Do siewu w korytach zmodyfikowano ramę siewnika polowego, aby umożliwić mocowanie sekcji wysiewających bocznie, a ciągnik mógł poruszać się obok koryta. Do siewu punktowego pod osłonami skonstruowano napędzany elektrycznie nośnik narzędzi, do którego może być mocowane urządzenie do przygotowania gleby (siew nawozów, dawkowanie biopreparatu mikoryzowego, spulchnianie i wałowanie podłoża), sekcje siewnika punktowego lub siedzisko do wykonywania plewienia.

Słowa kluczowe: przygotowanie gleby, siew punktowy, dozownik nawozów, uprawa w korytach, szkółki leśne

Accepted for print – Zaakceptowano do druku: 12.11.2012

For citation – Do cytowania: Walczyk J., Tylek P., 2012. Technical and technological progress in Polish forest nurseries. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 11(4), 45-55.