UDK 633.11:632.123
633.11:632.112

THE POSSIBILITY OF SUBSOIL UTILIZATION IN WINTER WHEAT PRODUCTION

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Abstract

Under normal circumstances, the topsoil dominates the process of supplying plants with water and nutrients. Under drought, however, being nearest the surface, it is the first soil layer to lose all its water. In such a situation, plants are forced to penetrate deeper into the soil with their root systems searching for water, in the process of which they reach the subsoil, which usually manages to retain more moisture then the topsoil. The objective of this study was to investigate the possibility of using the subsoil as an alternative source of water and nutrients. A two-year wheat trial with Mitscherlich's pots was established in which substrates from the topsoil (0-30cm) or the subsoil (30-60cm) was used. The substrates had been taken from a long-term experiment that included fertilized as well as non-fertilized plots. To these substrates, the following N rates were applied: no N, 0.5 g per pot, 1.0 g per pot, and 1.5 g per pot. The highest yields were found in the fertilized topsoil treatment with the highest N rate. More microbiological activity was observed in the fertilized topsoil substrates with higher N rates. Our study indicates that, once it has been activated (e.g. by deep plowing), the subsoil can provide a satisfactory alternative to the topsoil under dry conditions, regardless of the fact that it is effectively somewhat less fertile than the topsoil.

Keywords: Subsoil, yield, winter wheat, moisture, drought

Introduction

Droughts are a regular occurrence in the varying climate of the Vojvodina Province. Occurring every year, they last for longer or shorter periods of time, causing serious damage by decreasing yields of various agricultural crops (Bošnjak 1993a). The problem of drought in the Vojvodina Province has so far been addressed by a number of authors (Bošnjak 1993b; Stojšić 1994; Dragović and Labat 1993). In agricultural terms droughts have a particularly negative effect when happened to coincide with those stages of plant development at which plant water requirements are at their highest (Dragović et al., 1989).

The most direct measure in the fight against drought is irrigation (Dragović, 2001). Other, somewhat less efficient, measures are also available, such as the application of various agricultural practices of various adjustments to particular technological procedures used in crop production (Benedjschafie et al., 2008; Clark et al., 2007). The use of the conventional tillage system result in the formation of the topsoil down to plow depth as well as the formation of specific soil layer - the subsoil - right underneath (Šeremešić et al., 2006).

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The topsoil is more fertile, richer in available plant nutrients, and has better physical, biological, and air and water properties than the subsoil. Although its role consists in accumulating and preserving water, this soil layer will suffer a considerable loss of water under drought conditions, bringing about a decrease in microbiological activity, chemical and physical properties, and the release of plant assimilates (Lunch and Pantig, 1980, Tisdall and Oades, 1982; Pejić et al. 2005). Plants suffer from water deficiency and are unable to take up sufficient amounts of nutrients. In consequence, they are forced to penetrate deeper down into the soil with their root systems, in the process by which they reach the subsoil, which is usually better supplied with water under such circumstances.

This paper presents the results of a comparative study of the topsoil and the subsoil in terms of their suitability for crop production, aimed to determine if the subsoil can substitute for the topsoil in supplying plants with water and nutrients in dry conditions.

Material and Methods

A two-year wheat trial with Mitscherlich's pots was established under semi-controlled greenhouse conditions. The substrate soil was either from the topsoil (0-30 cm) or the subsoil (30-60) cm), and had been previously collected from fertilized or non-fertilized plots in a three-field crop rotation system (maize, soybean, wheat) established in 1946. Table 1 shows the chemical properties of the soil substrates used in the study. The chemical properties indicate significant difference in humus concentration and content of available phosphorus and potassium.

Table 1. – Chemical properties of the soil used in the study

Soil-management system (A)	depth cm (B)	pH		$CaCO_3$ (%)	Humus (%)	N (%)	mg/100 g soil	
		KCl	H_2O				P_2O_5	K_2O
Non-fertilized 3-year rotation (N3)	0-30	7.41	8.00	4.26	2.08	0.137	8.3	16.8
	30-60	7.62	8.03	12.78	1.83	0.084	5.0	12.7
Fertilized 3-year rotation (D3)	0-30	7.47	7.39	5.55	2.87	0.151	105.3	44.4
	30-60	7.63	8.11	17.47	1.87	0.120	47.6	21.0

At the beginning of the growing season, nitrogen (in the form of NH_4NO_3) was applied as follows: no nitrogen (control treatment), 0.5 g per pot, 1.0 g per pot, and 1.5 g per pot. In March, thinning was done at the final number of 15 plants per pot. The moisture of soil substrate was maintained by watering at an optimal level, between 70-80% of the water retention capacity of land in pot. The harvest is in full maturity of plants was made by cutting the stem to the ground surface. The data reported was assessed by analyses of variance (ANOVA). The analyses were conducted using the statistical software package Statistica 8.1. (StatSoft Inc., USA). The soli substrates were also analyzed in order to determine their microbiological properties.

Results and Discussion

Although the height of a plant depends primarily on its genetic base, it is also affected by environmental factors. In our study, as shown in Table 2, the tallest plants (48.6 cm) were those grown on the fertilized topsoil substrates to which 1.5 g of N per pot were applied and the shortest (32.3 cm) those from the non-fertilized subsoil treatment with no N added. All three factors under investigation proved to have a highly significant effect. Nevertheless, the soil layer was shown to have considerably less effect than the other two factors.

Table 2. – The height of the winter wheat plants (cm)

System of crop growing /A/	Depth cm /B/	Doses of nitrogen (g) /C/				Average /AB/	Average /B/	Average /A/
		K	0.5	1.0	1.5			
Non-fertilized 3-year rotation	0-30	34.8	38.1	42.0	43.1	39.5^{ns}		38.8B
	30-60	32.3	37.4	40.4	42.4	38.1^{ns}		
Average /AC/		33.5c	37.8b	41.2a	42.7a			
Fertilized 3-year rotation	0-30	37.2	42.3	44.6	48.6	43.2^{ns}		42.6A
	30-60	36.6	41.1	43.2	47.2	42.0^{ns}		
Average /AC/		36.9d	41.7c	43.9b	47.9a			
Average /BC/	0-30	36.0d	40.2c	43.3b	45.9a		41.3A	
	30-60	34.4d	39.2c	41.8b	44.8a		40.1B	
Average /C/		35.2d	39.7c	42.5b	45.3a			

$^{a\text{-}c}$Values in same rows followed by different letters do not differ significantly at P≤0.01; $^{A\text{-}B}$Values in same columns followed by different letters do not differ significantly at P≤0.01; ^{ns}-not significant

1000 grain mass is an important component of yield and is used as an indicator of yield quality. According to Drezgić et al. (1979), 1000 grain mass of wheat ranges between 33 and 45 g, averaging 38 g. In the case of our study, the values of this parameter turned out to be somewhat lower, which was due to the fact that the plants were grown in Mitscherlich's pots and semi-controlled conditions.

As Table 3 shows, the absolute 1000 grain mass was highly significantly greater in the fertilized treatments than in the non-fertilized ones. Furthermore, the values of this parameter proved to increase in parallel with an increase in the N rates applied, although the difference between the treatments with 1 g and 1.5 g of N per pot was found not to be statistically significant. Finally, the topsoil substrate produced a greater absolute 1000 grain mass – 32.9 g on average – than its subsoil counterpart (30.1 g on average), which is highly significant difference. These findings are in accordance with result presented in Milošev (2000) where soil fertility and climatic conditions had a significant effect on 1000 grain mass.

Table 3. – The absolute 1000 grain mass of winter wheat (g)

System of crop growing /A/	Depth cm /B/	Doses of nitrogen (g) /C/				Average /AB/	Average /B/	Average /A/
		K	0.5	1.0	1.5			
Non-fertilized 3-year rotation	0-30	28.2	30.2	33.8	33.9	31.5A		29.0B
	30-60	25.0	27.0	27.2	27.2	26.6B		
Average /AC/		26.6c	28.6b	30.5a	30.5a			
Fertilized 3-year rotation	0-30	28.1	35.0	36.6	37.7	34.3^{ns}		34.0A
	30-60	29.9	31.8	35.6	37.3	33.6^{ns}		
Average /AC/		29.0c	33.4b	36.1a	37.5a			
Average /BC/	0-30	28.1c	32.6b	35.2a	35.8a		32.9A	
	30-60	27.5c	29.4b	31.4a	32.3a		30.1B	
Average /C/		27.8c	31.0b	33.3a	34.0a			

$^{a\text{-}c}$Values in same rows followed by different letters do not differ significantly at P≤0.01; $^{A\text{-}B}$Values in same columns followed by different letters do not differ significantly at P≤0.01; ^{ns}-not significant

The total grain yield per pot is the ultimate indicator of how the factors in question affect grain yield in wheat. The highest yield of grain per pot (17.2 g) was found in the fertilized topsoil treatments to which 1.5 g of N per pot were added. The lowest yields (2.8 g) were those from the non-fertilized control treatments with subsoil substrates (Table 4). Although all of the factors under investigation had a highly significant effect, Table 4 shows that the yields were considerably less affected by the soil layer (topsoil or subsoil) used for substrates than by the other two factors. Being characterized by more biological activity, better aerial and thermal properties, and more available plant nutrients, the topsoil is more fertile than the subsoil and, consequently, gives higher yields.

Still, the yields obtained using the subsoil substrates were relatively high, indicating that this soil layer nevertheless has great potential in fertility terms. Its fertility can be activated by deepening the topsoil layer, for instances, by means of occasional deep plowing. The resulting improvement in the aerial and thermal properties of the subsoil will force it to activate both biologically and chemically, bringing about a more intensive release of available plant nutrients as well as a deeper penetration of the root system into this layer of the soil.

Having in mind all of this as well as the fact that the subsoil looses less moisture under drought than the topsoil, it can be said that the negative effects of drought can be mitigated to a certain extent by way of activating the subsoil. However, the ability of the subsoil to contribute to the yield formation could be limited with water logging, soil acidity or compacted layer at the plowing depth.

Table 4. – Winter wheat grain yields per plot (g)

System of crop growing /A/	Depth cm /B/	Doses of nitrogen (g) /C/				Average /AB/	Average /B/	Average /A/
		K	0.5	1.0	1.5			
Non-fertilized 3-year rotation	0-30	3.0	5.6	7.9	8.1	6.2A		5.1B
	30-60	2.8	3.7	4.1	5.3	4.0B		
Average /AC/		2.9c	4.7b	6.0a	6.7a			
Fertilized three-field	0-30	4.5	13.4	15.4	17.2	12.6A		11.5A
	30-60	4.3c	11.0b	13.1a	13.1a	10.4B		
Average /AC/		4.4c	12.2b	14.2b	15.1a			
Average /BC/	0-30	3.8c	9.5b	11.6a	12.7a		9.4A	
	30-60	3.6c	7.4b	8.6a	9.2a		7.2B	
Average /C/		3.7d	8.4c	10.1b	10.9a			

[a-c]Values in same rows followed by different letters do not differ significantly at $P \leq 0.01$; [A-B]Values in same columns followed by different letters do not differ significantly at $P \leq 0.01$; [ns]-not significant

As shown in Table 5, both the total number of bacteria and dehydrogenize activity were greater in the topsoil than in the subsoil substrates. In addition, there was more microbial activity in the fertilized treatments as well as in those to which mineral N was applied. Similar results of microbiological soil properties were presented in papers that investigated treatments from the same experiment (Đurić et al., 2004; Milošev et al. 2006)

Table 5. – Total number of bacteria and dehydrogenize activity

Systemof crop growing	Depth (cm)	Total number of bacteria 10^6 g^{-1} soil				Dehydrogenize activity g TPF 10 g^{-1} soil			
		Dose of nitrogen (g)				Dose of nitrogen (g)			
		0	0.5	1.0	1.5	0	0.5	1.0	1.5
Non-fertilized three-field	0-30	160.4	189.7	218.8	220.4	85.0	100.0	122.0	130.0
	30-60	67.2	115.0	121.1	115.1	20.0	45.0	70.0	110.0
Fertilized three-field	0-30	161.2	189.5	253.5	250.0	180.0	196.0	246.0	250.0
	30-60	70.0	120.7	121.6	126.5	90.0	96.0	152.0	160.0

Conclusions

The highest yields in our study were found in the fertilized topsoil treatments with the highest N rate. More microbiological activity was observed in the fertilized topsoil substrates to which higher N rates were added. Our findings show that the subsoil is effectively less fertile than the topsoil. Nevertheless, the yields obtained by using the subsoil substrates were relatively high, indicating that this soil layer is potentially highly fertile. It can be activated by deepening the topsoil layer (for example, by means of deep plowing), thus enabling the root systems to penetrate deeper down the soil horizon and providing plants with more water and nutrients. To a certain degree, therefore, the subsoil can substitute the topsoil under drought conditions.

Acknowledgments

This work was funded by the Ministry of Science and Education of the Republic of Serbia, project number TR031072.

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МОГУЋНОСТ КОРИШЋЕЊА ПОДОРАНИЧНОГ СЛОЈА У ПРОИЗВОДЊИ ПШЕНИЦЕ

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Сажетак

При нормалним условима ораничи слој земљишта преузима најважнију улогу у снабдевању биљака водом и хрњивим материјама. У сушним условима ораничи слој може имати ограничену способност да учествује у овим процесима. Услед тога долази до изражаја способност подораничног слоја да учествује у процесима снабдевање биљака водом и очувања приноса. Циљ наших истраживања је био да се утврди могућност и потенцијал подораничног слоја земљишта, као алтернативног извора хранива и воде за биљку, за формирање приноса. Продуктивност подораничног слоја је ипитана путем приноса пшенице, масе 1000 зрна и висине биљака. Двогодишњи експеримент у полуконтролисаним условима је изведен у Mitscherlich –овим судовима у којима је испитивано земљиште ораничног (0-30цм) и подораничног слоја (30-60цм). Земљиште (супстрат) је узето са вишегодишњег огледа на Римским Шанчевима. Испитивно земљиште је ђубрено растућим дозама минералног азота (0, 0.5, 1.0 и 1.5 г N). Највиши принос пшенице и најинтензивнија микробиолошка активност је добијена у ораничном слоју применом највеће дозе азота. Подоранични слој је активиран применом азота али добијени принос пшенице је нижи од ораничног слоја. Након активације микробиолошких процеса подоранични слој може да делимично може очествовати у формирању приноса у случају сушних година када ораничи слој, због ограничене приступаности влаге, изгуби своју улогу.

Кључне ријечи: Подоранични слој, принос, пшенице, влага, суша