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Research Article

THE IMPACT OF FRESH SAWDUST AND DRY PIG MANURE PRODUCED ON SAWDUST BEDDING APPLICATION ON THE NUTRIENTS MOBILITY IN SOIL AND SUGAR BEET YIELD

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ABSTRACT
The objective of the pot trial carried out at the area of the Slovak University of Agriculture in Nitra was to determine the impact of dry pig manure produced on the sawdust bedding and sawdust litter on the level of nutrients' mobility in the soil and sugar beet yield. The achieved results showed that one month after the sawdust and manure application to the soil, the contents of mobile nutrients (N_{an}, P, K, Ca, Mg) in soil were lower than in the control unfertilized treatment. The sawdust litter immobilized nutrients more considerably than manure. Four months after the manure application into soil, its immobilization effect was not evident. On the contrary, the manure increased the mobile nutrients content in soil. In the second year of experiment the immobilization effect of sawdust litter was proved even four months after its application into soil. The application of manure increased considerably the beet root yield. The maximum root yield was determined in the treatment where the highest dose of manure was applied. The minimum root yield was detected in the treatment where the highest dose of sawdust litter was applied.

Keywords: sawdust, pig manure, immobilization, sugar beet.

INTRODUCTION

Positive correlation between the dose of applied nutrients and their content in soil is determined in a standard manner. However, the relation between the dose of nutrients and their content in a mobile form in the soil can be not only positive, but also negative. Its evidence is determined by the selection of fertilizer, i.e. if the organic or inorganic fertilizer is utilized, or if we apply the fertilizer which increases biological or chemical sorption of nutrients or the fertilizer increasing the mobility of nutrients.

From the viewpoint of achieving high yields the total content of nutrients is not decisive but the content of nutrients in mobile or potentially mobile form is important [Havlin et al. 2004]. The content of mobile nutrients in soil is influenced by soil cultivation [Rembon and MacKenzie 1997], application doses of fertilizers [Reid 2002], selection of applied fertilizers and soil supplementary substances [Kjønaas 1999; Kováčik and Wiśniowska-Kielian 2009], irrigation [Misra et al. 2010], weather [Freckleton et al. 1999], use of pesticides [Števlíková et al. 2000], crop rotation [Conti et al. 1998; Lehmann et al. 1988], nutrients requirements of cultivated plants [Marschner 2005], dry and wet deposition [Tlustoš et al. 1999; Lacko-Bartošová et al. 2005], adjustment of soil reaction [Chang a Sung 2004] and by many other factors. One of them is also the quality of the applied organic fertilizers. The quality depends on the methods of manure fermentation. In Slovakia the unsatisfactory research attention is paid to the problems of manure fermentation in comparison to the neighbouring countries. The reason is also the fact that the production of farm manure has been falling for more than 20 years. The deficiency of organic fertilizers (cattle manure, pig manure, etc.) caused that the number of applications of low quality organic fertilizers in Slovakia has been increasing, in addition, in unsuitable periods and dosage, which leads to the negative influence on the yield and its quality as well as on the environment [Kováčik et al. 2010].

The objective of the experiment was to determine the impact of dry pig manure produced on the sawdust bedding and subsequently fermented for 7 days by larvae of housefly and fresh spruce sawdust on the contents of the available nutrients in soil and the yield of sugar beet roots.

MATERIAL AND METHODS

The pot trial was carried out at Slovak University of Agriculture in Nitra (48°18′ S, 18°06′ V) in the period of two years. In the first year the experiment started in October and in the second year in November. In the given months 23.5 kg of soil was put into the pots of 0.38 m height and diameter of 0.38 m. The soil was taken from the upper 0.0–0.3 m humus horizon Haplic Luvisol. In the process of soil weighing the tested organic fertilizers were applied into soil, what resulted in their equal mixture in the whole pot. After weighing the pots with soil were placed at dishes which were able to collect 1000 ml of the overflown soil solution in the period of precipitation. Agrochemical parametres of the used soil are shown in Table 1. The pig manure used in the experiment was fermented by larvae of housefly *(Musca domestica)* for 7 days. The manure was produced in the following way: the fresh manure taken from under nursing sow littered by spruce sawdust was placed at shelves evenly to the heigh of 0.2 m in the fermentation halls. The eggs of the housefly, which were obtained by breeding flies, were placed into the manure. The brooded larvae were processing manure for 7 days. Afterwards, they pupated. Immediately before the pupation the temperature increased slightly in the fermentation halls which led to the pupation on the manure surface. This enabled to collect most of the pupas. The pupas collection was not necessary from the aspect of manure production, however, it made the manure formation more effective. The humidity of the manure produced in this way was 30–40%. Afterwards, the manure was dried to 88.63% dry matter and ground. The principal chemical composition and nutrient contents of manure fermented by housefly larvae are given in Table 1.

In the experiment the same sawdust was used as it was added to the bedding in pig breeding (Norway spruce sawdust – *Picea abies*). The principal agrochemical parametres of sawdust are stated in Table 1. Table 2 shows the ratio between the total carbon content and the total nutrients contents in the organic materials.

The experiment was established with quadruple repetitions and it had 5 treatments (Table 3). During the dosage of pig manure fermented by larvae of housefly (tr. 2 and 3) the nitrogen content in manure was taken into consideration 172 kg•ha^{-1} N was applied by the dosage 8 t•ha^{-1} (tr. 3) (dose N complies with the Council Directive 91/676 EEC concerning the protection of waters against pollution by nitrates from agricultural sources). The dose 4 t•ha^{-1} (tr. 2) is a half dose of the treatment 3. The sawdust doses were selected so that they put the same quantity of the organic substance into soil as the used manure did. The identical quantity of the organic substances was put into soil by the dose 3.4 t•ha^{-1} of sawdust (tr. 4) as by the dose 4 t•ha^{-1} of manure, or the same quantity of the organic substances was put into soil by the dose 6.8 t•ha^{-1} of sawdust (tr. 5) as by 8 t•ha^{-1} of manure.

The contents of accessible nutrients in soil were probed in two periods: after one month and after 4 months from the foundation of experiments. The contents of the following accessible

Table 1. Agrochemical parametres of soil and materials used in experiment (dry matter)

Material	N_{an}	P	K	Ca	Mg	N_t	C_{ox}	C : N_t	Org.m.	pH/	pH/
	mg·kg^{-1}						%		%	KCl	H_2O
Soil 2009	14.8	66.25	430	1010	360	1358	1.34	9.9:1	4.61	5.66	6.07
Soil 2010	17.63	118.75	417.5	1355	385	1198	1.46	12.2:1	5.08	5.88	7.02
Manure	1030	1227	16 303	5839	451	19 686	40.04	20.3:1	81.99	7.53	7.65
Sawdust	187.5	9.65	436	872	171	794	50.21	632:1	98.22	4.36	4.87

Org.m – organic matter.

Table 2. Ratio of total carbon content to the content of total nutrients in tested materials

Material	C : N_t	C : P_t	C : K_t	C : S_t	C : Ca_t	C : Mg_t	C : Na_t
Manure	20.3 : 1	81.6 : 1	16.5 : 1	60.4 : 1	26.4 : 1	292.3 : 1	79.8 : 1
Sawdust	632 : 1	2231.6 : 1	401.7 : 1	662.4 : 1	174.6 : 1	529 : 1	1434.6 : 1

t – total

Table 3. Experiment treatments and application doses of tested materials

Treatment			Dosage	
no.	designation	specification	t•ha^{-1}	g/pot
1	0	unfertilized	-	-
2	M_1	manure, basic dose	4	111
3	M_2	manure, double dose	8	222
4	S_1	sawdust, basic dose	3.4	94.35
5	S_2	sawdust, double dose	6.8	188.7

nutrients N_{an}, P, K, Ca, Mg in soil were studied. The content of inorganic nitrogen was determined by the summation N-NH_4^+ and N-NO_3^-, where N-NH_4^+ was defined colorimetrically by Nessler agent and N-NO_3^- colorimetrically by the phenol 2.4 disulphonic acid [Kováčik 1997]. The accessible phosphorus, potassium, calcium and magnesium were determined according to the methodical procedure Mehlich III [Mehlich 1984]; P – spectrophotometrically, K and Ca – by flame photometry, Mg – by atomic absorbefacient spectrophotometry. The content of the total nitrogen was set by distilling after the minetralization of strong H_2SO_4 [Kjeldahl method]. The contents of P_t, K_t, Ca_t, Mg_t were determined after mineralization with the utilization of HNO_3 and $HClO_4$; P – spectrophotometrically, K and Ca – by flame photometry, Mg – by atomic absorbefacient spectrophotometry [Koppová et al. 1955]. The content of the total carbon was set oxidometrically [Ťjurin 1966], the content of the organic substances gravimetrically (550 °C), pH/KCl – potentiometrically (1.0 mol•dm^{-3} KCl).

Sugar beet sowing was carried out in the first decade of April in both years of the experiment. After sowing 6 seeds of the cultivar Antek, the soil surface was covered up evenly with 0.5 kg of siliceous sand. By the end of June the number of plants was 3 individuals, which remained until the end of the growing season. The experiment was completed in the second decade of October. The yield of sugar beet roots was determined by weighing. The acquired results were processed by mathematical and statistical method, by analysis of variance and linear regression analysis using Statgraphics PC program, version 5.0.

RESULTS AND DISCUSSION

The impact of the organic fertilizers on the contents of the accessible nutrients in soil was evident one month after their application into soil (Table 4). The maximum contents of N_{an}, accessible P, K, Ca and Mg were found evidential statistically in the control treatment. The detected data point out the inhibitive impact of the dry pig manure produced on the sawdust bedding and spruce sawdust on the mobility of all nutrients detected in the soil. The immobilization of nutrients was increasing with the growing dosage of manure and sawdust, the contents of the available nutrients in soil were decreasing. The sawdust litter inhibited nutrients in soil more considerable in comparison to the tested pig manure produced on the sawdust bedding. After the application of both tested organic substances regardless their application dose, the contents of the inorganic nitrogen were lowered most considerably. After the manure application the decreases of N_{an} varied in the interval from 6.08% to 18.79% and after the sawdust application they varied from 29.97% to 59.73% (Table 5). It is evident that one month after the sawdust application in the doses, which put the same quantity of organic substances as the farm fertilizers, cca 30 – 60% decrease of inorganic nitrogen content in soil is expected, which is a considerable descent. This kind of drop can be assessed as both positive and negative phenomenon [Kováčik 2013]. It can be assessed positively if the decrease occurs out of the growing season because it reduces considerably the nitrogen losses by leaching. The decrease is evaluated negatively if it is present during the growing sea-

Table 4 Impact of experiment treatments on the contents of available nutrients in soil (one months after foundation of experiment, November 2009 and December 2010, 100% dry matter)

Treatment		N_{an}		P		K		Ca		Mg	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
no.	des.	$mg \cdot kg^{-1}$									
1	0	14.90e	20.22d	85.6d	132.2c	472.5e	426.1d	1138c	1488b	439c	425d
2	M_1	13.45d	18.99c	82.5cd	128.6bc	447.5d	411.0c	1078b	1426a	390b	407c
3	M_2	12.10c	18.16c	79.4c	125.9b	427.5c	400.7b	1045b	1406a	383b	398bc
4	S_1	9.65b	14.16b	70.6b	120.4ab	410.0b	396.4b	1050b	1387a	393b	390b
5	S_2	6.00a	11.88a	58.8a	114.5a	390.0a	387.2a	1003a	1339a	320a	364a
$LSD_{0,05}$		1.083	0.992	3.231	6.123	15.400	8.546	32.710	90.304	12.050	10.284
$LSD_{0,01}$		1.567	1.341	4.792	8.024	22.423	9.627	47.603	97.774	17.537	11.314

No. – number, des. – designation, M – manure, S – sawdust, $LSD_{0,05}$ – limit of significant difference at the level $\alpha = 0.05$ (LSD test, different letter behind a numerical value respond to the statistically significant difference at the level 95.0%.

Table 5 Impact of experiment treatments on contents of available nutrients in soil expressed in relative percentage (one month after the experiment foundation)

Treatment		N_{an}		P		K		Ca		Mg	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
no.	des.	%									
1	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	M_1	90.27	93.92	96.38	97.28	94.71	96.46	87.08	95.83	88.84	95.76
3	M_2	81.21	89.81	92.76	95.23	90.48	94.04	84.41	94.49	87.24	93.65
4	S_1	64.77	70.03	82.48	91.07	86.77	93.03	84.81	93.21	89.52	91.76
5	S_2	40.27	58.75	68.69	86.61	82.54	90.87	81.02	89.99	72.89	85.65

No. – number, des. – designation, M – manure, S – sawdust

son as the grown plants fall behind their development, which is caused by the deficiency of the accessible nitrogen.

The decreases of accessible nutrients contents in soil after the sawdust application were expected because spruce sawdust contains low amount of total nutrients in relationship to the content of total carbon (Table 2). The rate C : N was higher than 30 : 1, which is the threshold value of the rate indicating immobilization N [Fotyma et al. 1987] and it achieved the value up to 632 : 1. Similarly, the rates C : P, but also C : S were higher than 300 : 1 and they proved unambiguously the biological sorption (immobilization) of phosphorus and sulphur. In the treatment 5, where the highest dose of sawdust (6.8 $t \cdot ha^{-1}$) was applied, there the lowest contents of the accessible nutrients were recorded out of all treatments of the experiment. The differences in contents of the accessible nutrients were statistically significant between the treatment 4, where 3.4 $t \cdot ha^{-1}$ of sawdust was applied, and the treatment 5 where the double dose of sawdust was applied (Table 4). The double dose of sawdust did not increase the nutrient immobilization in soil twice more intensively in comparison to the basic sawdust dose (Table 5 and 6). The recorded inhibitive impact of sawdust on nutrients was in accordance with knowledge of Čvančara [1964] and Kováčik et al. [2001].

The decreases of accessible nutrients' contents in soil were not expected after the application of dry pig manure produced on sawdust bedding (Table 4). Their recording was surprising as the rates of carbon to the content of total nutrients (C : N_t, or C : P_t and the like) in manure created the prerequisite for the fast mineralization of manure and the consequent increase of the contents of accessible nutrients forms in soil (Table 2). The decrease of the available nutrients contents in soil was statistically significant with the application dose 8 $t \cdot ha^{-1}$ of manure (tr. 3) in both years of experiment related to all five studied nutrients. The decreases of contents of the studied macroelements – apart from phosphorus - with the half dose of manure (4 t•ha^{-1} – tr. 2) were significant statistically as well (Table 4). The reason for recording the decrease of the accessible nutrients quantity in soil one month after the manure application was not the biological sorption. The rates of carbon to nutrients N, P, K, Ca and Mg were low. We assume that the reason was the chemical sorption increased temporarily. Its probable reason was the assumed increased quantity of the reactive organic groups in manure caused by the non-standard technology of manure production (fermentation by larvae of housefly. Stone and Wild [1977], Stevenson [1982a, b], Bielek [1998], Muneshwar et al. [1999] referred to the possibility that the organic substances would react with inorganic substances of soil solution where the stable organic compounds occur temporarily. Similarly, Yadvinder et al. [1988] first found out the decrease of inorganic nitrogen contents in soil after ploughing in manure and later their increase.

Table 7 shows the data related to the transience of decrease of the accessible nutrients contents in soil after the application of manure fermented by larvae of housefly. It is obvious that all determined nutrients contents in soil were statistically significantly higher four months after ploughing in manure, comparing to the contents in the control, unfertilized treatment, apart from Mg content in 2010 (tr. 2). The increased application dose of manure (tr. 3 versus tr. 2) was reflected as statistically significant higher content N_{an}, accessible P, K, Mg and also Ca in 2010. The learnt data point out the fact that the autumn application of the tested manure in the experiment does not cause shock because of the nutrient deficiency for the crops sown in spring or planted later. On the contrary, it leads to the increase of contents statistically significantly.

The transitoriness of the immobilization effect was evident not only after the manure application but also after the sawdust application (Table 7). In 2010 the content of the accessible nutrients was the same or higher with all the elements in comparison to the control treatment four months after the foundation of the experiment (tr. 4 a 5 versus tr. 1). On the contrary, in 2011 the contents of N_{an}, accessible K, Mg and partially also P were lower than the contents of the given elements in the control treatment. These facts proved that what determines the decay and synthesis processes in soil is not only the quality of the used organic substances, which are given by the rate of carbon to nutrients (C : N, C : P, etc.), but also the cultivating year (weather de-

Table 6 Impact of double dose of sawdust on contents of available nutrients in soil expressed in relative percentage (one month after the experiment foundation).

Treat-ment		N_{an}		P		K		Ca		Mg	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
no.	des.	%									
4	S_1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
5	S_2	62.18	83.89	83.29	95.10	95.12	97.68	95.52	96.54	81.42	93.33

Table 7 Impact of experiment treatments on the selected soil parametres (four months from the experiment foundation, 3rd March 2010 and 30th March 2011 – 100% dry matter)

Treatment		N_{an}		P		K		Ca		Mg	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
no.	des.	mg•kg^{-1}									
1	0	9.00a	17.8c	48.75a	127.50b	367.5a	285.00b	1070a	1398a	311.5a	314.50b
2	M_1	16.70b	32.0d	105.00c	246.25c	435.0c	347.50c	1140b	1595b	317.5a	347.13c
3	M_2	25.25c	38.4e	175.00d	432.50d	515.5d	438.13d	1350e	1528b	387.5c	376.51d
4	S_1	11.00a	16.4b	60.00b	131.25b	385.0b	277.50b	1185c	1558b	367.5b	304.46a
5	S_2	9.60a	12.3a	68.75b	96.25a	385.0b	263.75a	1205d	1385a	370.0b	298.73a
$LSD_{0,05}$		2.132	0.621	10.708	12.236	17.068	7.914	19.97	119.59	8.52	7.049
$LSD_{0,01}$		3.102	0.903	15.581	16.858	24.84	10.904	29.06	164.77	12.39	9.712

No. – number, des. – designation, M – manure, S – sawdust, $LSD_{0,05}$ – limit of significant difference at the level $\alpha = 0.05$ (LSD test), different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

velopment). The more organic substances with the low nutrient contents are put into soil the longer the process of immobilization is. In order to prevent the deficit of mobile nutrients in soil it is needed to apply the fertilizers containing significant quantities of organic substances ahead of time before the plant sowing. Kováčik [2013] recommends to apply the high quality manure at least 6 weeks before the plant sowing and the low quality manure at least 3 or 4 months before sowing. The achieved results show that the sawdust should be applied more than 4 months ahead of time before plant sowing. This usage of sawdust enables the producer to save money for the nitrogen and other nutrients purchase. These nutrients are not leached out from soil due to immobilization. The sawdust application creates the prerequisite for sufficient access of nutrients to the cultivated plants. In case of the sawdust usage in the short period before plant sowing not only the evidence of insufficiency of several nutrients can be expected but also lower yields.

The differences in the sawdust impact on the contents of mobile nutrients in soil -recorded between 2010 and 2011 - were also evident in the yield of sugar beet roots (Table 8). In 2011 – the year when the process of immobilization of N, K, Mg and partially P appeared even before the sugar beet sowing (Table 7) - lower yields by 31.3 and 35.8% were recorded in the treatments 4 and 5 in comparison to the control treatment (Table 8). On the contrary, in 2010 - the year when the increase of the accessible nutrients content in soil was monitored in the pre-sowing period of beet in the treatments 4 and 5 – there in the treatment 4 48.46% increase of yield was achieved and in treatment 5 there was a yield decrease. The drop was insignificant and it did not reach 5%. The results affirm that in order to prevent the negative impact of sawdust application on the yield of cultivated crop it is important either to apply nitrogen with sawdust in a form of artificial fertilizers, or to carry out nitrogen fertilizing before the plant sowing itself. The same results were confirmed by Jančich et al. [2012].

The impact of the tested pig manure fermented by larvae of housefly on the yield of sugar beet roots was statistically significantly positive in each year. As a result of manure application in the dose of 4 t•ha^{-1} the yield of beet roots increased from 70.7 to 75.4%. The double dose of manure increased the yield of roots from 143.7 to 220.8%. In the experiments of Kováčik et al. [2010] the differences in the yield of sunflower achenes were not significant between the application doses 4 t•ha^{-1} and 8 t•ha^{-1} of pig manure fermented by larvae of housefly.

The recorded unambiguously positive impact of the dry pig manure produced on the sawdust bedding by the fermentation of housefly larvae on the yield of sugar beet roots opposes to the opinion of Lacko-Bartošová et al. [2005], who claim that the types of manure produced on the sawdust bedding require fermentation taking the period of six months.

On average of both years the lowest root yields were detected in the treatment with the double dose of sawdust (tr. 5). Sawdust impact on root yield with both application doses was not statistically significant on average in both years of the experiment. On the contrary, the impact of the dry pig manure produced on the sawdust bedding and fermented only during seven days by larvae of housefly was significant. The manure utilization increased the yield of sugar beet roots significantly. Higher application dose of manure resulted in higher root yield. The yields increases

Table 8 Impact of experiment treatments on the yield of sugar beet roots (fresh phytomass)

Treatment		Yield					
		2010		2011		average	
no.	designation	g/pot	rel. %	g/pot	rel. %	g/pot	rel. %
1	0	192.43 a	100.00	249.03 b	100.00	220.73 a	100.00
2	M_1	328.46 b	170.69	436.88 c	175.43	382.67 b	173.37
3	M_2	617.26 c	320.77	606.92 d	243.71	612.09 c	272.11
4	S_1	285.68 b	148.46	171.09 ab	68.70	228.39 a	103.47
5	S_2	184.08 a	95.66	159.82 a	64.18	171.95 a	77.90
$LSD_{0,05}$		92.321		88.003		94.878	
$LSD_{0,01}$		127.662		119.741		128.992	

No. – number, M – manure, S – sawdust, $LSD_{0,05}$ – limit of significant difference at the level $\alpha = 0.05$ (LSD test), different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

Table 9 Dependence between the yield of sugar beet roots and content of mobile nutrients in soil determined before beet sowing expressed by correlation coefficient r

Parameter		Correlation coefficient
dependent	independent	r
Yield of tuber	N_{an}	0.8508++
	P	0.7688++
	K	0.7568+
	Ca	0.3421
	Mg	0.7109+

varied about 73% (tr. 2), or 172% (tr. 3). The statistically significant correlations (Table 9) were determined between the roots yield and the content of mobile nutrients in soil set before the beet sowing. These facts prove the findings of several authors [Dowdel et al. 1983; Bízik 1989; Kováčik 2009] that the most important is N_{an} specified in the pre-sowing period for the calculation of the nitrogenic fertilizers dosage.

CONCLUSION

One month after the sawdust application and manure application, which was produced on the sawdust bedding, the contents of mobile nutrients (N_{an}, P, K, Ca, Mg) in soil were lower than in the control unfertilized treatment. The most distinctive drop was that of inorganic nitrogen. N_{an} contents decreased by 29.97% even 59.73% after the sawdust application and by 6.08% even 18.79% after the manure application. The sawdust immobilized nutrients more significantly than manure. With the growth of manure and sawdust doses the immobilization of nutrients was increased.

Four months after application of manure in soil its immobilization effect was not present. On the contrary, manure increased the content of mobile nutrients (N, K, Ca, Mg) in soil. In the second year of the experimenmt the immobilization effect of sawdust was evident even 4 months after its ploughing in soil.

There was an evident correlation between the content of the accessible nutrients in soil (N_{an}, P, K, Mg), determined before beet sowing and the yield of beet roots.

Manure application increased significantly the yield of beet roots. The highest root yield was found in the treatment with the highest manure application. The lowest root yield was observed in the treatment with the highest dose of sawdust application.

Sawdust application is recommended to be used four months ahead of time of plant sowing. In the case of sawdust application in soil, it is needed to fertilize by nitrogen before sowing itself. The application of manure produced at the sawdust bedding should be carried out four months before the plant sowing. In the experiment of the tested manure the autumn application does not cause shock from nutrients insufficiency to the plants sown in spring or to the planted crops. On the contrary, this kind of application leads to the statistically significant increase of nutrients' contents.

From the viewpoint of plant cultivation it is necessary to reappraise the opinions stating the need of six months for the fermentation of manure produced at the sawdust bedding.

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