Influence of windrow composition on composting by a windrow turner

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ABSTRACT: A PKS 2,8 tractor-drawn compost windrow turner was used on three different types of compost windrows. The consistence 810, 654 and 354 kg/m^3 and the change of profile sizes in given sections were monitored inclusive of the course on band-shaped windrows. The windrow turner operational speed and turning course were also observed. On the basis of the measured values, the windrow turner real performance was determined for each windrow that reached the values of 71–197 m^3/h.

Keywords: compost windrow composition; windrow turner performance

Residual biomass constitutes a large spectrum of materials that can successfully and effectively be processed into compost providing that appropriate mechanisation is used (ŽUFÁNEK 1997). Linkages for composting should be recommended according to the character of compost material. Experiments on horticultural residual biomass composting were carried out at the Department of Horticultural Mechanization, Faculty of Horticulture in Lednice from 1999 to 2001 (VEVERKA 1999).

The PKS 2,8 tractor-drawn compost windrow turner prototype that was designed with a three-point linkage adjustments of this machine (ZEMÁNEK et al. 1997) was modified (on the basis of previous experience) to a semi-trailed windrow turner PKS 2,8.

The goal of this paper was to evaluate the performance of the set consisting of windrow turner plus tractor (called windrow turner set), to determine the loosening coefficient and the changes of profile sizes on compost windrows of different composition.

MATERIAL AND METHODS

A modified windrow turner attached to a Z 7211 tractor equipped with a crawler speed (up to 300 m/h) was used on three different compost windrows of similar dimensions. The trapezoid-shaped windrow width maximally reached 2.5 m and had different heights. Therefore the width of the compost windrow had to be adjusted to 2.5 m by shovel loader UNC 060. It contributes to better homogenization before the first windrowing. The compost windrows consisted of various elements.

This is clearly given in Tables 1, 2 and 3. The values given in percents express the volume of individual components in compost windrow.

Table 1. Windrow A – Velké Bílovice (silo emplacement)

Material	Proportion (%)	Volume weight ρ_v (kg/m^3)	Quantity in windrow (m^3)
Grapes pressing	41	460	110
Apple pressing	8	620	20
Grape rachis	12	164	30
Straw	4	200	10
Clay – earth	23	1,120	60
Semi-liquid manure	12	1,000	30
Total m^3			260
Mixture before turning		654 ± 30	k_N = 1.42
Mixture after turning		460 ± 15	
Theoretical calculation of mixture capacity		643	

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Table 2. Windrow B – Lednice-Nejdek

Material	Proportion (%)	Volume weight ρ_v (kg/m^3)	Quantity in windrow (m^3)
Grass material	69	250	100
Straw	21	500	30
Hay, manure	10	350	15
Total m^3			145
Mixture before turning		354 ± 40	k_N = 1.23
Mixture after turning		295 ± 23	
Theoretical calculation of mixture capacity		312	

Windrow A: dominance of wine marc, structural coarse material.

Windrow B: dominance of grass clippings from Lednice Castle park, straw material, non-preprocessed.

Windrow C: dominance of earth and barks, structural material.

The weigh of the loading volume 0.405 m^3 was used to determine the volume weight of each component of compost windrow. The consistence of the mixtured before and after turning was determined by weighing 5 samples in the loading volume 0.405 m^3. Theoretical calculations of mixture consistence are mentioned for comparison in tables.

Windrow turner performance was calculated as follows:

$$W_{02} = 60 \,.\, v_p \,.\, S \text{ (m}^3\text{/h)}$$

where: v_p (m/min) – the operational speed of the windrow turner set, determined by the calculation of the turning time in a given section.

We measured the performance 5 times and then we calrtated the average value of the windrow turner performance including deviations.

S (m^2) is the surface of the turned windrow profile in a given section.

Loosening coefficient was calculated as follows:

$$k_N = \frac{\rho_{V1}}{\rho_{V2}}$$

where: ρ_{V1} – the mixture volume weight before turning,
ρ_{V2} – the mixture volume weight after turning.

RESULTS AND DISCUSSION

The results of measurements carried out on windrows A (Velké Bílovice, dominance of wine marc, volume weight 654 kg/m^3) are indicated in Table 4. The 2.5 m wide windrow reached a profile height of 0.95–1.10 m and an operational speed of 1.77–2.60 m/min. The movement of the windrow turner set was regular, the calculated performance ranged between 152 and 248 m^3/h, the average performance was 197 m^3/h. The loosening coefficient reached 1.42.

In the case of these windrows, it was necessary to correct the width of the windrow back to 2.5 m before each turning because the coarse material enlarged the width of the pile. This was done with a loader or with a tractor scraper.

The results of measurements carried out on windrows B (Lednice-Nejdek, dominance of straw material that was not pre-processed, volume weight 354 kg/m^3) are indicated in Table 5. The height of the layer that reached 1.5 to 1.8 m when carried in decreased to 0.70–0.85 m during the 16 weeks preceding the first turning. The width of the windrow did not practically change. His therefore clear that the measured consistence 354 kg/m^3 was changing quickly. The operational speed of the set ranged between 0.34 and 0.75 m/min. The performance of the windrow turner set was 39–90 m^3/h during the first turning, the average performance reached 71 m^3/h. The coefficient of air content was 1.23.

When turning windrows B, the rotor was obstructed with straw material that had to be removed from the rotor quite often (sometimes even once every meter). The part of the compost, especially the top layer of the

Table 3. Windrow C – Lednice, Faculty of Horticulture

Material	Proportion (%)	Volume weight ρ_v (kg/m^3)	Quantity in windrow (m^3)
Earth	50	1,240	75
Bark	30	320	45
Horticultural wastes	20	140	30
Total m^3			150
Mixture before turning		810 ± 15	k_N = 1.21
Mixture after turning		670 ± 8	
Theoretical calculation of mixture capacity		744	

Table 4. Windrow turning A – Velké Bílovice (silo emplacement). Measured and calculated values for determination of windrow turner production rate

Section	Section length L (m)	Windrow turning time T_p (min)	Operational speed v_p (m/min)	Windrow height H (m)	Cross-section surface S (m^2)	Set production rate W_{02} (m^3/h)	Average value W_{02} (m^3/h)
1	8	4.5	1.77	0.95	1.43	152	
2	8	3.5	2.28	1.05	1.81	248	
3	8	3.0	2.60	1.10	1.35	210	197 ± 14
4	8	3.5	2.30	1.10	1.35	186	
5	8	3.2	2.50	1.00	1.25	187	

Table 5. Windrow turning B – Lednice-Nejdek. Measured and calculated values for determination of windrow turner production rate

Section	Section length L (m)	Windrow turning time T_p (min)	Operational speed v_p (m/min)	Windrow height H (m)	Cross-section surface S (m^2)	Production rate W_{02} (m^3/h)	Average value W_{02} (m^3/h)
1	10	16	0.625	0.70	1.80	67.5	
2	12	35	0.342	0.80	1.90	39.0	
3	20	30	0.666	0.77	1.95	78.0	71 ± 8
4	15	20	0.750	0.80	2.00	90.0	
5	22	37	0.590	0.85	2.25	79.80	

windrow was well proceeded and well homogenised by the rotor. This effect was manifested mainly during the 2 following turnings. However, the performance of the windrow turning set remained about the same because during shrinking, a next diminution of the profile to 0.40–0.60 m occurred.

The results of measurements carried out on windrows C (Faculty of Horticulture, Lednice, dominance of barks and soil, volume weight 810 kg/m^3) is indicated in Table 6. The height of the windrow was constantly 1.0–1.1 m, the operational speed reached 1.20–1.40 m/min. The calculated performance of the windrow turner set ranged between 144 and 184 m^3/h, the average performance was 170.6 m^3/h. The loosening coefficient reached 1.21.

Relative comparison of the values is illustrated in Fig. 1.

For that type of windrows, it was necessary to keep the width of the pile at 2.50 m, otherwise problems with the tractor and the windrow turner occurred and the windrow turner was being lifted. The increase in the volume weight was also expressed by an increase in the windrow turner power requirement. However the fuel consumption was not directly observed.

The windrow turner performance of 700–1,200 m^3/h declared by the prototype manufacturer for an operational speed of 2.7–3.0 m/min was not achieved in any case. The main reason is that the surface of the turned windrow section was always smaller than the theoretical capacity of the windrow turner (4.32 m^2). The operational speed was comparable.

The coarse material enables the highest performance of the windrow turner but at the same time requires the pile to be preformed very often.

Straw granular material shrinks a lot and the small height of the pile profile decreases the windrow turner performance. Most time and energy consuming is first windrowing here (sometimes in accordance with material type and second windrowing). After that, it is possible to turn the windrows in smaller time intervals and to make the composting process faster.

Materials including high amount of soil with highest capacity weight 810 kg/m^3 enables the highest perfor-

Table 6. Windrow turning C – Lednice, Faculty of Horticulture. Measured and calculated values for determination of windrow turner production rate

Section	Section length L (m)	Windrow turning time T_p (min)	Operational speed v_p (m/min)	Windrow height H (m)	Cross-section surface S (m^2)	Production rate W_{02} (m^3/h)	Average value W_{02} (m^3/h)
1	5	3.8	1.32	1.0	2.20	174	
2	5	4.1	1.22	1.1	2.40	176	
3	5	3.9	1.28	1.1	2.25	172	170 ± 6
4	5	4.2	1.20	1.0	2.00	144	
5	5	3.6	1.40	1.1	2.20	184	

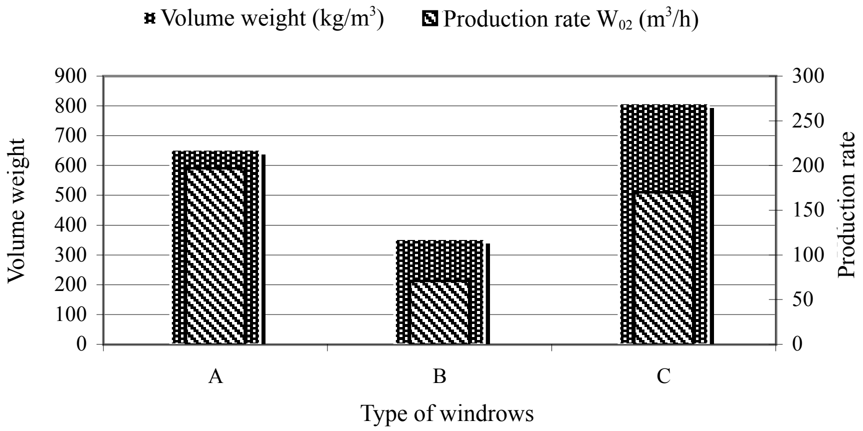

Fig. 1. Windrow volume weight and windrow turner production rate

mance of windrow turner, but it requires a modification of the windrow shape to keep the requisite latitude 2.50 m because the form to the windrow of this type will be destroyed by the turning process.

The loosening coefficient reached the highest values in windrows with a dominance of wine marc that had the character of a coarse material, which corresponded to the hypothesis about lack of granular structure in windrow.

The windrow volume weight mainly influences the performance because the flat blades must penetrate a harder material.

For straw material and mainly at the beginning of the process (1st and 2nd turning) flat blades without any lateral cutting edge break or bend the material, and it consequently obstructs the rotor, which decreases the performance of the windrow turner set. For this type of material, it is recommended to construct a rotor equipped with blades, which really cut the material.

When operating on a 2.5 m width, windrow turners must be designed as semi-trailers whatever the windrow composition is. It is because three-point linkage machines do not have the necessary stability and do not keep the right direction when operating on 2.5 m wide windrows. It results in destroying the pile's form, frequent necessary stops and low set performance.

CONCLUSION

The measurements proved a very good effect of structural characters of compost windrow for reached windrow set performance. Next, we can formulate a hypothesis that a modification of the rotor operational blades is the way to increase to real performance of the windrow turner for dominant windrow components.

Until now, the tendency has been to design a universal windrow turner, but in future on we should concentrate the possibility of adapting the rotor operational blades on the windrow turner to the windrow composition.

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Vliv složení kompostové zakládky na výkonnost překopávací soupravy

ABSTRAKT: Traktorový rotorový překopávač kompostu PKS 2,8 byl nasazen na třech různých typech kompostových zakládek. U zakládek tvaru pásových hromad s objemovou hmotností 810, 654 a 354 kg/m^3 byla sledována změna rozměrů profilu v daných úsecích a pracovní rychost překopávací soupravy včetně celkového průběhu překopávání. Z naměřených hodnot byla u každé zakládky stanovena skutečná výkonnost překopávací soupravy, která dosahovala hodnot 71–197 m^3/h.

Klíčová slova: složení kompostové zakládky; výkonnost překopávače

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