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Compost conditioning by the use of low temperature compaction for better dosing behaviour

For some time compost is due to the nutrient content and attractive costs a valuable substrate in agriculture. In addition, the application to preserve potato and grain legume crops is interesting because of the proven suppressive effects. Fundamental problems by applying bulk compost are the special material properties and the problems with a precise application. The following article analyses the shape of compacted compost as a basis for a precise in-row application. The objective of this investigation is the creation of defined material properties while retaining the suppressive effects. The results show that it is possible to produce compost pellets in a mesophilic region which can be applied with commercial equipment while maintaining suppressive properties. In addition, the shape of the pellets can be adapted to the shape of seeds to produce homogeneous mixtures. The interaction of the mechanical strength and the solubility of the pellets in the soil still have potential for additional improvements.

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Abstract
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The positive suppressive effects of a bulk compost application to control several pathogens are well known since a long time. To produce a high yield it is necessary to suppress the pathogens and protect the crops against losses. A number of studies verified these suppressive effects of compost, in particular, for grain legumes like peas and fava beans [1; 2; 3]. Thus, the suppressive effects against *Pythium ultimum* resulted in significantly higher fresh matter yield of peas under controlled conditions. It was shown that in principle the higher the compost application the better was the disease suppression [4]. Therefore, it was hypothesized that a target application of compost would likely lead to a better suppressive effect than in a broadcast application. To achieve these yield effects also a precise compost application of 5 t DM/ha in the planting row showed very promising results. However, the in-row application of bulk compost requires a costly specific metering device [5; 6] as a result to overcome the strong bridging effects and the weak flowability of the compost material. Therefore, our research effort was put on a further improvement of the physical material properties of compost especially its flow and metering characteristics through a compaction of the substrate known as pelletizing. Subsequently, the quantity of material on the seeder or planter could be substantially reduced. However, the retaining of the suppressive effects is important. In the case of *Phoma medicaginis* the process and the effect were already proven [3]. Additionally, a slow nutrient release was observed in the cited study.

An appropriate mean to form single particles to bigger compounds in bores is the mean of pelletizing. Normally the friction of the material in the bores heats up the compounds (pellets) to 60 °C [7]. Since the suppressive effects are based on microorganisms which colonize the compost after the sanitization with temperatures between 35 and 40 °C [4; 8; 9] this high temperature might lead to detrimental effects. Therefore, the temperature during the compaction process should not exceed 40 °C. An additional temperature rise above this value leads to an inactivation of the microorganisms and therefore destroys the suppressive effect. This is the reason why the adjustment of the pelleting press must be chosen in a way that the critical temperature threshold is not exceeded and that the production of the pellets is carried out in the mesophilic region from 20 to 40 °C.

A dependency of the suppressive effect on the diameter of the pellets has not been scientifically proven [3]. Hence, the shape can be adapted to existing metering devices e.g. seeders and fertilizer spreaders. The adaption to the shape of seeds to produce mixtures of seeds and pellets is also possible.

Material and Methods

The compost for the experiments was produced from greenwaste. The compost substrate was sieved at 10 mm. No additives e.g. starch, paraffin or molasses were added. The following flat die pelleting presses were used:

- 6 mm bore diameter (7.5 kW drive power, 230 mm die plate diameter, 30 mm bore lenght),
- 8 mm bore diameter (75 kW drive power, 800 mm die plate diameter, 40 mm bore lenght).

The support pressure of the pan grinder rollers was adjusted low enough so that the material was put in the bores without any interruption. Temperature was measured continuously using a strap-on thermocouple. The recorded average temperature was 35 °C and never exceeded 40 °C. The following parameters were tested on the produced pellets:

Dry mass content

The determination of the dry mass content was done by the gravimetric method in a cabinet dryer at 105 °C over 24 h.

Bulk density

The bulk density was measured with a special measuring container (capacity: 2 209 cm^3). The content was compressed through three hits [10].

Grain size distribution

The amount of the different particle sizes was measured with a vibrating sieve set (sieve sizes: 8; 6.3; 4; 3.15; 2 and 1 mm), time: 15 min, 4 repetitions [11].

Mechanical strength

For the determination of the mechanical strength the pellets were sieved (> 3.15 mm) and the fraction > 3.15 mm were put into a test box (ASAE Standard S269.4) and rotated for 10 min with a speed of 50 rpm. After the treatment the sample was put on a sieve (> 3.15 mm) a second time and the fraction (< 3.15 mm) was weighted again [12; 13].

Dimensions

To estimate the possibility of a mixture of pellets and seeds the sizes of both were determined. For that a sample of 100 g of pellets, 25 g of peas and 45 g of fava beans were collected. The body length and diameter of each was measured with a crosswise measurement [14].

Resistance to fracture (solubility)

For the final analysis of pellet solubility a percolation experiment was selected as with this experiment the start time and the duration of dissolution can be measured with high accurancy. As there were no results from previous studies with compost pellets a special baseline investigation was necessary. For a first estimation of the potential solubility the strength of fraction was measured under dry and wet conditions with a peek hold needle penetrometer (capacity: 0.5 to 60 kg, 40 repetitions). The diameter of the surface ground plunger was 4 mm (12.57 mm^2). The necessary 15 min of water contact to generate a clear softening was determined in pre-experiments. To estimate the impact of a pre grinding of the compost material on the pellets solubility these experiment include also 6 mm pellets which are produced from ground raw material (Grain size: 4 mm) with the same press adjustment.

Table 1

Bulk density and dry matter content of bulk compost and compost pellets

Material/*Material*	**Schüttdichte *Bulk density* [kg/m³]**	**Trockensubstanz *Dry matter* [%]**
Loser Grünschnittkompost *Bulk greenwaste compost*	390	65.8
Kompostpresslinge *Compost pellets*	690	79.4

Results

Bulk density and dry mass content

Through the pellet process the bulk density of the compost rises from 390 to 690 kg/m^3 (**Table 1**). The dry matter content rises from 65.8 to 79.4 %.

Grain size analysis

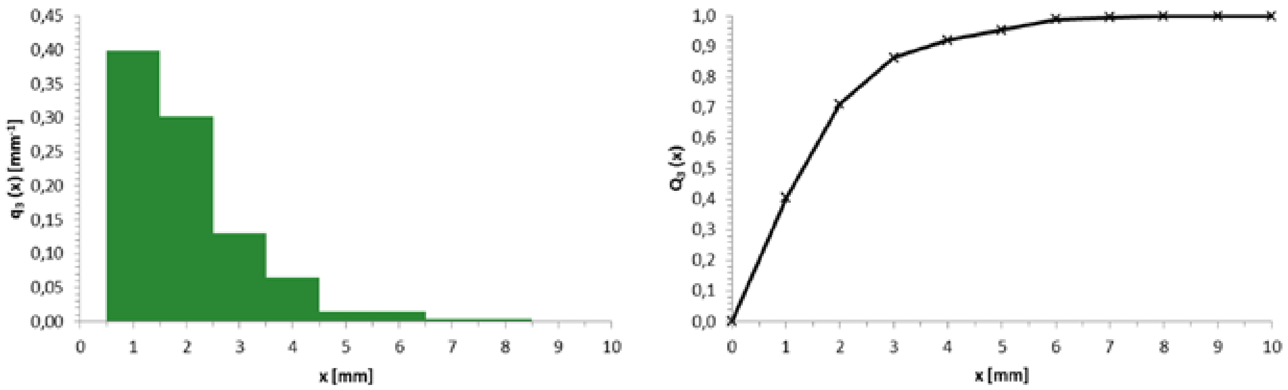
Figures 1 to **3** show the particle size frequency distribution (q3, left) and cumulative distribution sum (Q3, right) of bulk compost and compost pellets [15]. From them it is evident that bulk compost consists in more than 90 % of particles with a size below 1 mm. Particles of size greater than 6 mm make only about 2 % of the total mass (**Figure 1**).

Through processing the raw material in a flat die pelleting press with 8 mm bore diameter about 70 % of the pellets are in the > 8 mm category and 1 % of the mass is smaller than 1 mm (**Figure 2**). For stability reasons the length of pellets from a bore are between a diameter of 8 mm is 9 mm. For this reason some of the pellets refer to the category > 8 mm. In the case of pellets from a 6 mm bore diameter the biggest part of the total mass is in the sieve category > 4 mm to < 6.3 mm. In this case the diameter to length ratio is equally uneven (1:1.65) so that a part of the pellets goes through the sieve of < 6,3 mm (**Figure 3**).

Mechanical strength

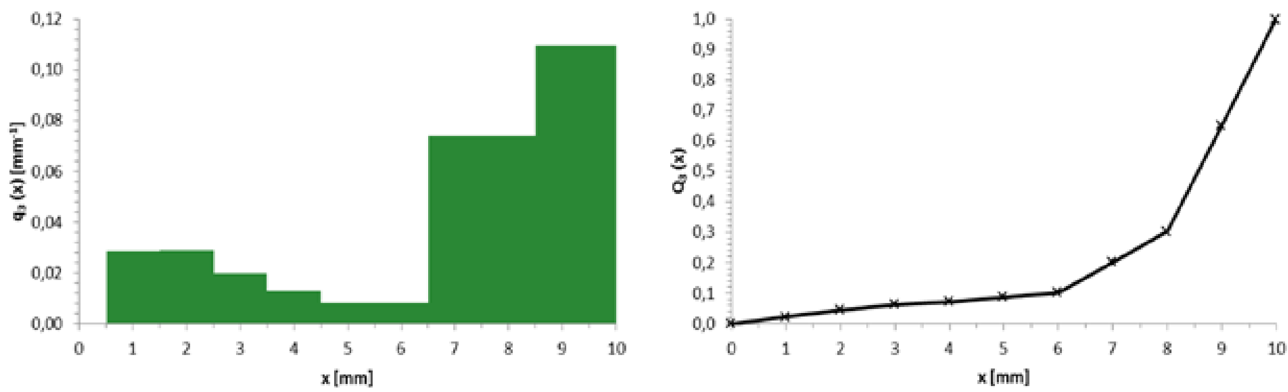
The experimental results of the mechanical strength shows in the case of the 6 mm pellets 95.2 % undamaged compounds and 4.8 % rubbed-of parts (84.9 % DM). The 8 mm pellets have 90.4 % undamaged compounds and 9.6 % rubbed-of parts (86.5 % DM).

Fig. 1



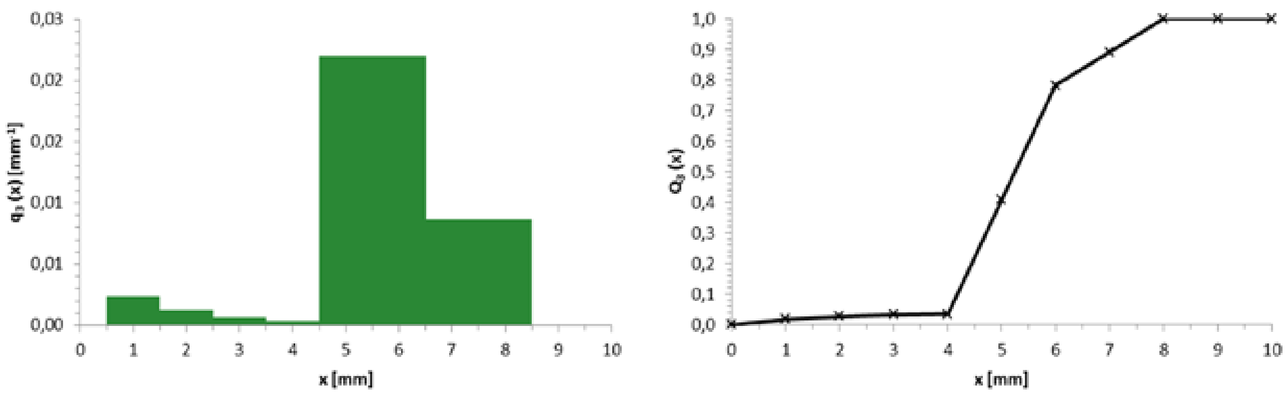
Distribution density and distribution sum of bulk compost

Fig. 2



Distribution density and distribution sum of 8 mm pellets

Fig. 3



Distribution density and distribution sum of 6 mm pellets

Dimensions

The average diameter-length ratio of the 8 mm pellets is 1 : 1.4. The ratio of the 6 mm pellets is 1:1.65. In the case of summer and winter peas the ratio is equal, soybean has a ratio of 1 : 1.31 and fava bean of about 1 : 1.49 (**Table 2**).

Resistance to fracture (solubility)

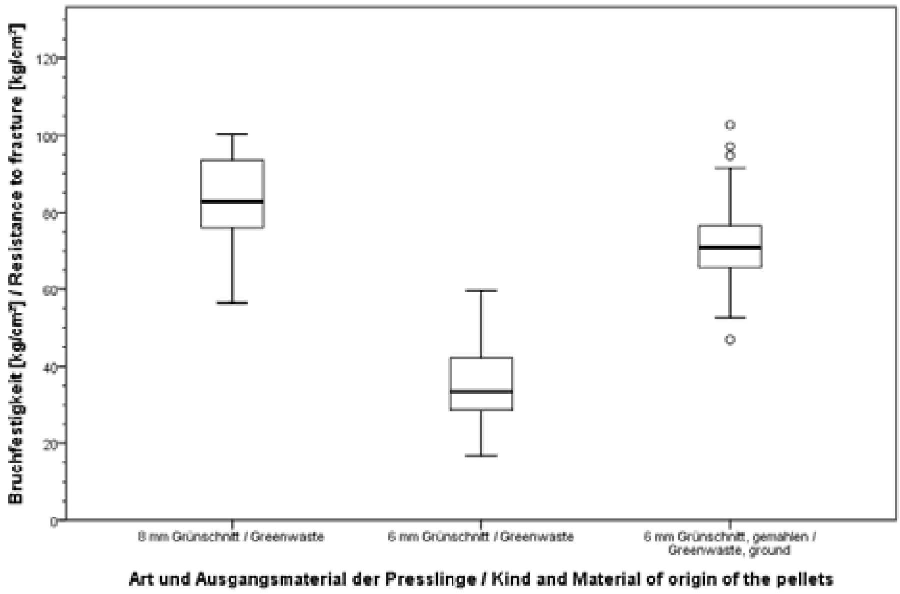
The range of the measured mean values varies from 35.11 kg/cm² (pellets 6 mm diameter) to 82.55 kg/cm² (pellets 8 mm diameter) in dry condition (**Figure 4**). The 6 mm pellets from ground compost show no significant different results. The box-

Table 2

Dimension of the measured pellets and seeds

Material/*Material*	**Durchmesser/*Diameter* [mm]**	**Länge/*Length* [mm]**	**Verhältnis von Durchmesser zu Länge *Ratio of diameter to length***
8-mm-Pressling/*8 mm pellet*	7.5	10.5	1 : 1.4
6-mm-Pressling/*6 mm pellet*	5.9	9.7	1 : 1.65
Sommererbse ‚Casablanca‘/*Summerpea ‚Casablanca‘*	7.3	7.3	1 : 1
Wintererbse ‚EFB 33‘/*Winterpea ‚EFB 33‘*	5.6	5.6	1 : 1
Ackerbohne ‚Bilgo‘/*Field bean ‚Bilgo‘*	7.0	10.3	1 : 1.49
Sojabohne ‚Gallec‘/*Soybean ‚Gallec‘*	5.2	6.8	1 : 1.31

Fig. 4



Resistance to fracture in dry condition (> 80 % DM)

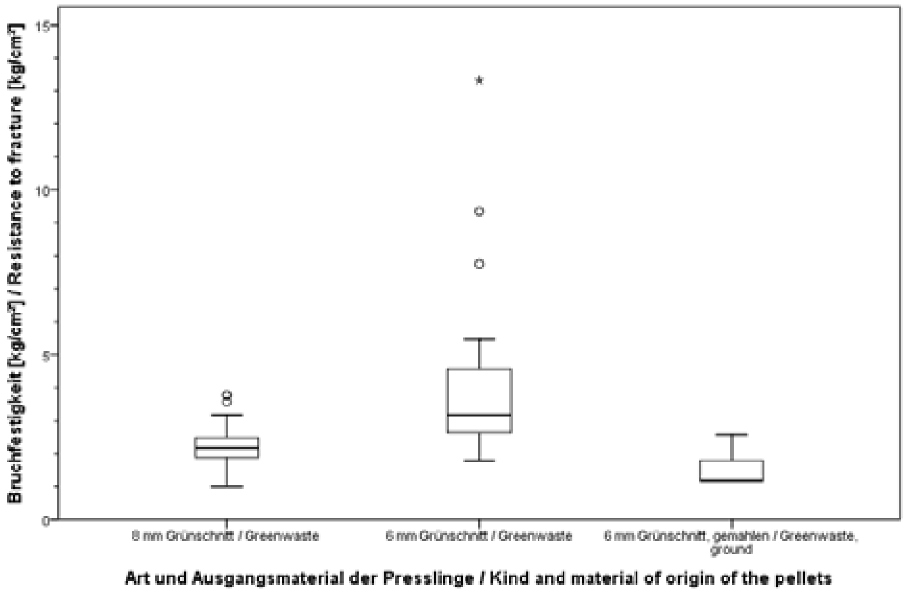
plot shows the results in boxes and whiskers. The lower and upper edges of the box correlate with the lower and upper quartile. Therefore the edges of the box represent the median 50 % of the samples. The whisker ends are the lowest and highest value of the sample. Outlier and extreme values are shown as stars and circles [16].

After wetting the pellets the results are the following. The 6 mm pellet from ground compost had the lowest resistance 1.59 kg/cm² and the 6 mm pellet from greenwaste showed the highest value with 3.97 kg/cm² (**Figure 5**). Overall the results are closer together after wetting the pellets than under dry conditions.

Discussion

The compaction of compost in a mesophillic area leads to a significant decrease of the specific volume and has a drying effect on the compost substrate. In the pelletizing experiment the dry matter content of the compost increased by 13.6 % in the process. A higher dry matter content improves the storage properties based on the lower risk of mold development and leads to an easier application because of the lower adhesion between the single bodies. The experiments to examine the mechanical strength showed that over 90 % of the pellets keep their geometrical size. At the first view the part of fines seems very high with 4.8 to 9.6 % but in an earlier experiment with two common fertilizer pellets (Maltaflor® and Solafert®) with an equal design as for our compost pellets we could find 4.76 % and 0.89 % of fine particles, respectively [17]. Therefore, the fraction of fine parts in the compost pellets is comparable to the fertilizer pellets. The results for the distribution density and the cumulative distribution show the change in the material properties due to the pelletizing process. The similar geometrical size of the 6 and 8 mm pellets and the seeds of fava bean and soybean are very interesting for a mixed application **(Table 2)**. Based on the geometrical size a mixture of both materials for the application with common machines seems possible but the bulk density of

Fig. 5



Resistance to fracture in wet condition (time: 15 min)

the seeds is only one half of the pellets density and a separation of the mixtures in the seed tank seems to be unavoidable. In this case a mixing device would be helpful. The expected uneven distribution of the seeds in the planting row in the mixed application needs also to be considered. The solubility of the pellets in the soil is very important as the microorganisms need to colonize the area near the plant roots to perform an optimal suppressive effect and in addition to facilitate the nutrient uptake by the plants. The results of the experiments to measure the resistance to fracture show that under dry conditions solid and strong pellets have a 10 to 20 times lower crushing strength than under wet conditions. For the practical solubility in the soil there are still some limitations. On the one hand the mechanical impact of the pellets after the application is rather small and on the other hand the precipitation after the planting time is sometimes a limiting factor for sufficient moisture in the soil and also for the swelling of the pellets. To solve these problems the construction of a device which can bring a defined amount of water to the pellets or destroy their geometry would be helpful. This device would lead to a better solubility.

For the determination of the impact of different raw materials and conditioning processes the starting point and the rate of solubility should be monitored in the field. A percolation experiment would be suitable for that task. The dissolved substances would be detected shortly after the water related swelling of the pellets in the soil.

Conclusions

The physical conditioning of compost can be an interesting alternative to the bulk application. A sophisticated construction of the metering device is not necessary because of the possibility to handle the pellets with common seeders and fertilizer spreaders. An interdepartmental cooperation between soil sciences, phytopathology, plant production and agricultural engineering is necessary to optimize the interaction between the application device, the fast solubility of the pellets in the soil and the reliable effect in the field.

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