LIFE-Vitisom: a EU project for the set-up of VRT organic fertilization in vineyard

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Abstract In the vineyard, the organic fertilizer spreading in VRT mode is difficult, because the various matrices used show typically a remarkable variation in their physical parameters, such as the size, water content, density, etc., mainly due to their very different original sources and managing operations. The EU LIFE-Vitisom project (LIFE15 ENV/IT/000392) focuses on the set-up of organic fertilizer spreaders, able to the distribution in VRT mode in vineyards.

The VRT distribution was based on prescription maps (i.e. referred to the plant vigour) or, as an alternative at the beginning of the growing season, using a set of sensors reading locally and in real time the branches dimension. The field tests were carried out in 2017 and 2018 seasons, and were devoted to measure the spreading quality in VRT mode of three matrices (manure, solid digestate and compost), by comparing the theoretical (implemented in the software) and the real rates distributed. In respect to the acceptable deviation (± 20%), the results show values exceeding the limit in a significant number of tested conditions. A possible solution (at present under investigation) is to vary the bulkhead speed (i.e. the matrix flow to be distributed) not only considering the prescription map or the local sensors signals, but also taking into account the material density increase from the beginning to the end of a single spreading routine.

1 Introduction

The Variable Rate Technology (VRT) is at present applied at several agricultural crops, and represents any operation which enables producers to vary the rate of inputs. Regarding the fertilization, on the market are nowadays already available many models of spreader equipped with devices able to distribute granular and powdery inorganic (mineral) fertilizers, adopting the VRT solution.

In some cases, the contribution of organic fertilization can be fully alternative to that inorganic (*Celik et al., 2010; Morlat and Chaussod, 2008*). However, the organic matrices (especially those distributed in solid state) show very different physical characteristics. In fact, each of them can differ remarkably in size, fiber amount, water content, etc. Moreover, each of these matrices show a wide variation of the physical-

chemical composition, basically function of the raw materials. As a consequence, applying the VRT to organic fertilization could become sometime quite difficult.
The most popular organic fertilizers used in Italy are manure, solid digestate and compost (**fig. 1**).

Figure 1 The most popular matrices used for the organic fertilization in Italy, also in vineyards and orchards.

More in detail:

- the manure usually derives from cattle breeding, but the fiber content depends greatly on the type of litter adopted and on the diet of the animals;
- the solid digestate is basically function of the raw materials subjected to anaerobic digestion;
- the compost characteristics depend on the nature and the amount of each single starting component, which could originate from agricultural, industrial or civil wastes.

This wide variability often implies into considerable difficulties in the application to the soil, which can be performed either with traditional methods, i.e trying to carry out a uniform distribution over the entire surface, or by varying the dose locally in VRT mode, according to the needs of the crop (*Landry et al. 2004; Metzger et al., 2010*).
The organic matrices show a very complex rheological behaviour, due to a triphasic system of elements (solid components, water and air): in fact they are materials that do not behave exactly like solids, but not even like fluids. Depending on their composition, if subjected to compression or torsion stresses, they can have a so-called "Newtonian" or "non-Newtonian" behaviour *(Bjorn et al., 2012; Mani et al., 2004)*
More in detail, the manure usually has a typical size very different from the compost, being less homogeneous (*Amiri et al., 2012*). The water content greatly influences the reaction of this matrix. In the compression tests, the water content affects the absorbed force value, determining different levels of compaction of the sample. The behaviour features of the solid fraction of the digestate very often derive from the uniform feeding of the digesters with maize silage; nevertheless, being that a matrix recently introduced, there is no at present a deep knowledge on this matter.
In general, but of course also in specialized crops (vineyards and orchards), the VRT application brings significant advantages of pesticide and fertilizers (both mineral and organic) spreading (*Rückamp et al., 2013*). This is of great importance in the organic viticulture, of increasing interesting worldwide.
The VRT distribution is usually based on prescription maps (i.e. referred to plant vigour) or, as an alternative especially before and at the beginning of the growing

season, using a set of infrared and/or optical sensors, reading locally and in real time the canopy extent and/or the branches/shoots dimension (the diameter). These data are used to determine the rate of the organic matrices to be distributed in the various area of the vineyard. The distribution is normally executed with spreaders equipped with rear rotors, fed with a bulkhead moving horizontally into the hopper, both with fixed and variable rate (**fig. 2**).

Figure 2 Two of the spreader prototypes manufactured for the Vitisom project: the towed self-levelling (left) and the straddle self-propelled (right) models

The Vitisom project (LIFE15 ENV/IT/000392), funded by EU Commission inside of the LIFE framework, started in 2016 to develop an innovative technology to manage vineyard organic fertilization. The project aims to the implementation of the VRT to upgrade the vineyard organic fertilization distribution systems and to promote a more sustainable approach to vineyard soil management, also extendable at EU level. More in detail, the Vitisom project focused on the manufacturing of 5 prototypes of organic fertilizer spreaders, being them towed or self-propelled and traditional or self-levelling. They were selected for the best management efficiency, taking into account the slope and the breeding features of the italian vineyards. The prototypes were designed to distribute the organic fertilizers in VRT mode, for a theoretical rate from 0 to 40 t/ha.
The aim of this study is to verify the distribution quality of the described models in VRT mode, for the three matrices considered, over a range of distribution rates and for different travelling speed values.

2 Materials and method

The first spreader is based on a traditional single-axle trailer, with a wooden hopper of approx 3 m³ capacity, hydraulically driven working parts, and a series of sensors and actuators devoted to VRT distribution mode. A movable bulkhead conveys the material loaded into the hopper towards a couple of horizontal rotors, which thanks to a rear shield drop the product onto a couple of finned disks rotating in the horizontal plane, which finally provide for the spreading of the fertilizer on the ground.

The fully hydraulic driving of the machine, as well as the hydraulically tiltable towbar, allow extremely reduced turning radius, assuring an excellent maneuverability in vineyard. Furthermore, the towed prototype is equipped with an automatic hopper leveling system and servo-controlled hydraulic brakes, so considerably improving the safety, especially when working on slope.

In detail, the VRT mode is managed thanks to two hydraulic motors controlled by an encoder, which varies the rotation speed of the rear distribution rotors and the translational speed of the bulkhead conveying the matrix towards the rear rotors inside the hopper. Based on the position of the machine (georeferenced by GPS), the software defines the amount distributed, which is basically inversely proportional to the canopy vigour. The canopy vigour is ascertained through previously built-up prescription maps, or alternatively using the real-time detection, thanks to a series of dedicated sensors fitted in front of the tractor.

The machine is completed by a couple of sloping bulkheads, to facilitate the correct loading of the hopper, and a couple of moving chains joined by transversal bars placed on the hopper bottom, helping the matrix to be conveyed towards the rear rotors.

The self-propelled version of the organic fertilizer spreader is similar to the towed model; the only (important) difference is that the distribution module is fitted on board of a straddling tool-carrier, suitable for work in vineyards having inter-rows of less than 1,8 m width, where the tractor-driven version cannot travel (**fig. 3**).

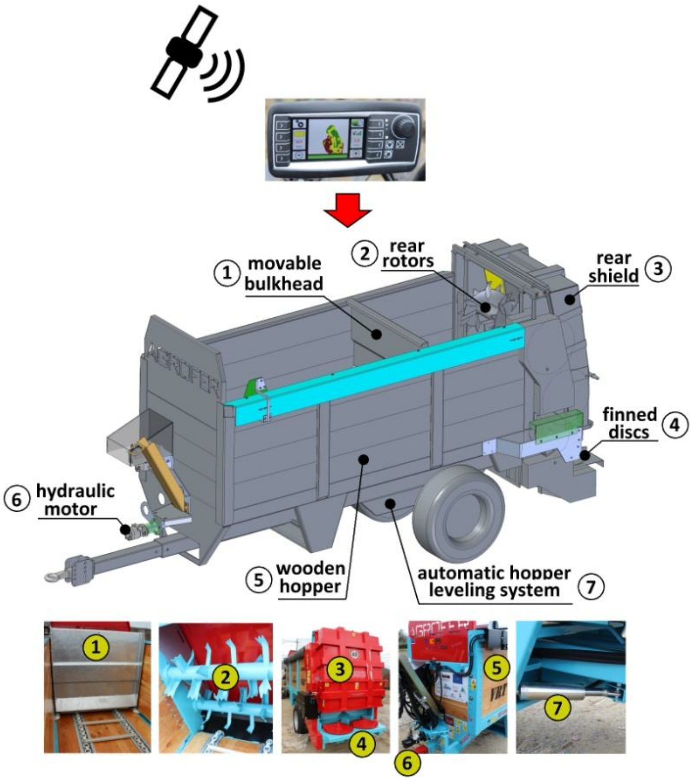

Figure 3 Technical details of the towed version of the spreader

To ascertain the distribution efficiency in VRT mode of the two spreaders, two test procedures have been arranged, being them different in the detail of the data obtained.
The first method considered the material amount distributed on an entire inter-row, resulting from the difference of the measurements of the spreader gross weight at the beginning and at the end of a given inter-row travelling. The amount distributed was then compared to what expected, considering the prescription map indications for that investigated inter-row. To carry out the trials, a weighing system including four mobile digital platforms (mod. WWS, sold by Vincro Bilance, Rovereto, TN - Italy) was purchased, to be placed under the wheels of the machine (**fig. 3**). In this case, only three platforms were used, and placed under the single-axle wheels of the spreader (two of them) and the third under the parking jack, assuring that all the weight was loaded on the sensors.

Figure 3 The weighing system including 4 mobile digital platforms used in the tests

The second solution involved the measurement of the rate distributed in specific areas in the inter-rows, selected also in this case on the basis of the prescription maps. Some plastic sheets (length: 6 m; width: 2.5 m max, for a max covered area of 15 m²) of convenient thickness were placed in the inter-row in which the spreader was travelling and in their proximal inter-row(s). The aim was to collect and weigh the amount of matrix distributed by the machine in each area surveyed (**fig. 4**), and then compare the measured with the expected data. For weighing the samples, a digital dynamometer (make Marsden, Rotherham, GB, model OCS-S1, 1,000 kg_f full scale) was used.
A particular care was devoted to select areas in which the due rate was constant and likewise as far as possible to its variation, in order to be sure the machine was working at the rate imposed by the correspondent reading of the prescription map. Moreover, time by time the reference working width was adjusted according to the width of the inter-rows and to the machine setting. Starting from the surface covered by the plastic sheet(s), the rate was calculated by dividing the weight of the material collected (i.e. that distributed along the length considered) for the reference area.
The described field tests were carried out in 2017 and 2018, respectively at the end of the growing season (i.e. after the grape harvesting) and before the beginning of the next one, when no canopy was present in the vineyard, so without any heavy canopy interference during the spreading.

Figure 4 The amount of matrix distributed by the machine in each inter-row surveyed, and collected on the plastic sheets of known surface (left), was later weighed by using a digital dynamometer and compared with the expected figure resulting from the prescription map (right)

The test were repeated in four different vineyards, located in North and Centre Italy (Guido Berlucchi, Borgonato di Corte Franca (BS); Castello Bonomi, Coccaglio (BS); Conti degli Azzoni, Montefano (MC); Premiata fattoria di Castelvecchi in Chianti, Radda in Chianti (SI)), using all the prototypes manufactured. Only the test results carried out during 2018 in the Castello Bonomi and Guido Berlucchi wine farms are reported in this paper; in any case the data obtained in the other sites are fully in line with those shown and commented in the following. In Castello Bonomi the towed self-levelling prototype was used, while in Guido Berlucchi the self-propelled straddle type has been working. In the two farms both the testing methods were applied. To assess the performance of the spreaders, for each test condition the following data were measured:

- working width, total working area and area of the sheets;
- target dose related to the test (kg/m² and t/ha);
- dose measured on the entire inter-row area (kg/ha) and on the sheets (kg/m²);
- absolute deviation from the target, on the sheets and on the inter-row area.

3 Results and discussion

Table 1 shows the data obtained at Castello Bonomi with towed self-levelling prototype, considering the two testing methods.

Taking into account the single runs, the absolute deviations from the target value varied from a minimum of 2% on manure (target 3 t/ha) to a max of approx. 67% for the digestate (target 10 t/ha).

Table 1 Absolute deviation of the distributed dose with the towed self-levelling prototype in comparison of a range of target dose, for the three considered matrices, used in Castello Bonomi wine farm

Target dose, t/ha	**10**			**5**			**3**		
Matrix	manure	digestate	compost	manure	digestate	compost	manure	digestate	compost
Entire-row method									
Absolute deviation, %	24.8	51.8	56.4	22.5	48.7	43.1	***2.0***	33.5	40.6
Plastic sheets method									
Absolute deviation, %	24.0	24.6	33.0	66.7	***14.1***	***15.6***	75.3	***16.2***	24.4

In general, from a cultivation point of view, an absolute deviation of 20% in respect to the target dose was considered as acceptable, due to the possibility that the fertilizing potential of a matrix could share on the surroundings of the distribution point.

However, during the tests only in 4 cases on a total of 18 this limit was respected; no significant difference was highlighted considering the 3 matrices performances, but in general for the target dose of 10 t/ha for manure, 5 t/ha for compost and 3 t/ha for digestate the lowest deviation values were recorded.

For manure, a possible reason of such a behaviour may be justified considering the non-uniform texture of the material; in other words, when the dose is decreasing, the spreader shows a poor performance, highlighting wide amount variations of the material distributed along the travelling direction (**fig. 5**). This feature has been detected also with the other two matrices, but the solid digestate and even more the compost show a more uniform texture, so minimizing the problem.

Figure 5 Examples of uniform (left) and non-uniform (right) distribution in the travelling direction

An other problem observed during the working was a non-uniform distribution at the starting and at the end of each single routine, mainly due to a discontinuous feeding of the rear rotors.
Moreover, it was observed that the problem becomes worse after a long transferring between two vineyards.
This is probably due to the vertical (for the gravity) and horizontal (for the movement of the bulkhead) remarkable compaction to which the matrix is subjected inside the hopper, resulting in undesired heaps along the inter-row, followed by empty areas (**fig. 6**), so resulting in severe distribution errors.

Figure 6 Due to the probable vertical (for the gravity) and horizontal (for the movement of the bulkhead) remarkable compaction to which the matrix is subjected inside the hopper, the material is very poorly distributed, resulting in undesired heaps along the inter-row, followed by empty areas.

In **table 2** are shown the results obtained with the self-propelled straddle prototype tested in Guido Berlucchi wine farm. In this case, depending on the matrix distributed, the target does was different, but in all the cases, both for entire inter-row and plastic sheets methods, the absolute deviation exceeded (sometime remarkably) the ±20% limit.
This is due to a general malfunctioning of the spreading module, that was at a first extent poorly adaptable to the tool-carrier to which it was coupled.
Moreover, with this straddle prototype a large part of the product fell on the plants, smearing them, and a significant transverse difference of the distributed product on the soil was detected.

Table 2 Absolute deviation of the distributed dose with the self-propelled straddle prototype in comparison of a range of target dose, for the 3 considered matrices, used in Guido Berlucchi wine farm

Matrix: **MANURE**			
Target dose, t/ha	**20**	**10**	**5**
Entire-row method			
Absolute deviation, %	74.8	41.6	65.4
Plastic sheets method			
Absolute deviation, %	24.1	61.2	55.9
Matrix: **DIGESTATE**			
Target dose, t/ha	**33**	**22**	**11**
Entire-row method			
Absolute deviation, %	41.1	22.1	12.9
Plastic sheets method			
Absolute deviation, %	57.0	54.4	76.1
Matrix: **COMPOST**			
Target dose, t/ha	**15**	**10**	**5**
Entire-row method			
Absolute deviation, %	87.3	37.5	51.5
Plastic sheets method			
Absolute deviation, %	75.9	86.7	89.5

4 Conclusions

The two tested prototypes showed a good capacity in varying the distribution rate inside of the target range. Nevertheless, due to the rheological characteristics of the organic fertilizers investigated, some difficulties in assuring a regular feeding of the rear rotors were detected, so resulting in high deviations of the materials rate distributed, when compared to those expected.
One of the probable reasons of these malfunctions is the vertical (for the gravity) and the horizontal (for the bulkhead movement) compaction to which each matrix is subjected when conveyed to the rotors.
To solve the problem, it will be necessary to pilot the speed of the base mat and the movable bulkhead, not only in relation to the dose to be distributed and to the travelling speed, but also taking into account the progressive compaction caused on the material by the two moving parts.

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