Seed treatment with SIPERNAT® specialty silica and AEROSIL® fumed silica

Technical Information 1406

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1 Introduction

These days seed treatment is a very efficient and eco-friendly method to protect seeds and seedlings against the most common diseases and vermin that are frequently present on fields used for agricultural purposes. An important seed treatment technology such as seed granulation reduces the entire amount of seed applied onto the field and maximizes yield at the same time. Another effective seed treatment technology is seed coating. Fungicidal or insecticidal active ingredients incorporated into the coating protect seeds used to cultivate of a multitude of crops. The effects of unforeseeable fungal infections or insect damage on seedlings still germinating in the soil can be so serious that the growth of the plants can be significantly delayed or even terminated. Seed coating technology in particular contributes to sustainability as an ecologically-friendly type of plant protection because the amount of fungicides and insecticides used is tremendously lower compared to area spraying or to granule application along the seed row.

Thus both technologies contribute to a more environmentally-friendly cultivation of the seeds and plants which are needed to satisfy the worldwide growing demand for crop based feedstock as a prerequisite for sustainable and modern agriculture and food production.

1.1 Basic principles of seed treatment

Seed treatment technology differs by seed and by formulation type. Seed coatings or encrustation is the most popular seed treatment. In this method the seed surface is smoothened and the seed weight is increased by ca. 3–50 %. Whereas the seed weight can be increased by > 50 % if the seeds are pelletized (granulated). The thinnest layer on seeds can be achieved by film coating technology with smaller than 3 %. The advantages of sowing a pellet seed based on granulation technology are many. Besides the reduced seed rate and the enhanced harvest, the regular shape and defined size of granulated seeds allows an individual and precise sowing of high-value seeds such as rape seed, vegetable seeds, flower seeds, white mustard and fodder radish. The advantages of the seed granulation process are summarized in **Figure 1** below.

Figure 1
Advantages of seed granulation

A granulation process that builds up a pellet or layer covering the seed offers the following advantages...

- **regular shape and defined sized.**
- **adjustable density.**
- **individual and precise drilling.**
- **enhanced harvest.**
- **reduced application rates.**
- **trace elements, micro nutrients and active ingredients (AI)**

With the help of SIPERNAT® specialty silica the advantages of granulated seed can be further extended with regard to the germination, the germination duration as well as the seed emergence in the field. SIPERNAT® specialty silica functions to bring water through the shell matrix into the core of the seed that would otherwise be hindered by the shell. Thus a comparable or better germination behavior versus common, non-granulated seed can be obtained. In the end special, newly developed and tailor-made seed treatments can differentiate themselves from the products being currently offered on the market.

Another important method of seed treatment is the application of a liquid coating–the so-called seed coating–onto the seed's shell. This enables a more efficient crop protection as the application rate per hectare can be reduced considerably. However only a stable pesticide formulation is able to fulfill the standards required today for a highly developed and highly efficient seed protection formulation. One of the most efficient methods is to incorporate AEROSIL® fumed silica as a rheology modifier and stabilizer into oil or water based formulations. The fumed silica forms a reversible three-dimensional network that allows the viscosity to be adjusted and also keeps the active ingredient (AI) particles well-suspended and dispersed in the liquid. A higher viscosity improves the adhesion of the stabilized coating to the seed. The typical shear thinning behaviour of liquids containing AEROSIL® fumed silica ensures good pourability and sprayability and therewith a good distribution and performance in the field. **Figure 2** provides a summary of the benefits obtained by the use of AEROSIL® fumed silica in liquid coatings.

Figure 2
Advantages of AEROSIL® fumed silica in seed coatings

Rheology control for example of liquid insecticide, fungicide, biocide, plant booster and plant strengthener coatings with AEROSIL® fumed silica offers...

- **viscosity adjustment.**
- **prevention of AI settling and re-agglomeration.**
- **increased storage stability.**
- **easy pouring without waste.**
- **better drying and coating.**
- **improved adhesion on the matrix.**
- **faster drying–reduced seed coating machine cleaning.**

Besides the stabilization of seed coatings by the adjustment of the viscosity using AEROSIL® fumed silica, the addition of SIPERNAT® specialty silica products confers certain functionalities and benefits to special coating formulations applied onto the outer shell of a seed embryo. The use of SIPERNAT® products in seed coatings can help to smoothen the surface roughness of uneven or furrowed grains with the result in an improvement of their flow characteristics. Good flowability is a prerequisite if encrusted seeds are to be transported and packed automatically. Due to its hydrophilic nature and unique absorption capacity, SIPERNAT® specialty silica has several advantages in seed coatings. First, it improves the flowability of the coated seeds; second, it accelerates the coating drying by acting as a highly absorptive ingredient in the outer shell; third, SIPERNAT® grades may be used as carriers for sticky or highly viscous insecticide- or fungicide formulations. In addition to hydrophilic SIPERNAT® and AEROSIL® products, hydrophobic grades are also available. The hydrophobic–water repellent–nature of these products provides a protecting layer if incorporated in the shell matrix or the coating of the seeds sensitive to moisture or mold. **Figure 3** below shows the beneficial effects of SIPERNAT® specialty silica.

Figure 3
Advantages of SIPERNAT® specialty silica in seed coatings and incrustation processes

SIPERNAT® speciality silica can be used as an ingredient that offers...

- **flow improvement of encrusted or granulated seeds.**
- **improved drying as highly absorptive ingredient in the outer shell of a seed granule.**
- **a carrier for sticky and highly viscous insecticides and fungicides.**
- **reduced penetration of water to moisture sensitive seedlings (hydrophobic silica).**

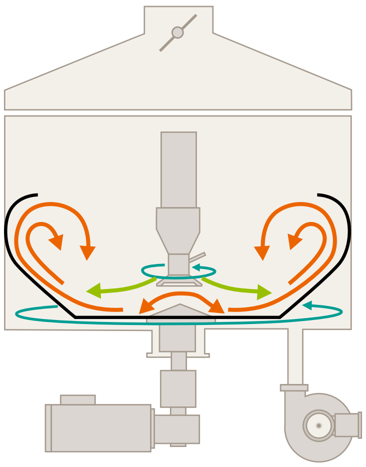
Evonik Industries AG has addressed the challenges and opportunities of seed treatment applications and offers a wide range of products for the treatment of a large variety of crop seeds. With our know-how and technical expertise in the use of our products in these applications, we support you in developing the appropriate processing and handling conditions to enhance the quality of your seed products.

1.2 Seed granulation process

The rotation granulation process that is used for the manufacturing of granulated seeds is shown schematically in **Figure 4**. In the first preparation step the untreated seeds are added manually or automatically into the rotation vessel. A double stage water dosing system moisturizes the seeds, typically by use of a spraying disc.

In the next production step the shell mixture is added through an inlet by a screw feeder. The moisturization of the seeds ensures a good adhesion of the shell matrix onto the grains' surface. This operation is supported by special binding agents such as long chained polyvinyl alcohols. In general the process is a so called build-up granulation whereby layer upon layer (shell matrix and binder) is applied onto the seed core. Once the desired granulation size is obtained the build-up granulation process is finished and followed by a drying step. Afterwards a coating step is common in order to apply a liquid insecticide or fungicide coating as a mordant. Both processes enable a more efficient protection of the seed embryo sowed into the soil through forming a protective dye zone around the seed. Both the mordant as well as the fungicide/insecticide coatings need to be stabilized during storage. A very effective stabilization method is the incorporation of AEROSIL® fumed silica to build up a stabilizing three-dimensional network that prevents settling and re-agglomeration of the added solid active ingredients. The use of AEROSIL® fumed silica as rheology modifier is described in detail in Chapter 5.

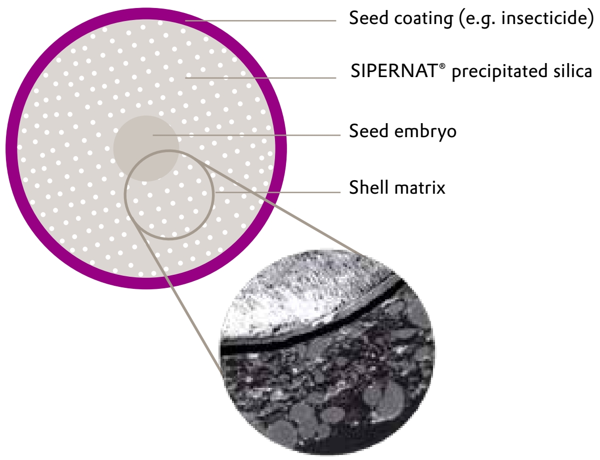
Figure 4
Principle of the RPS Rotation and Pelletizing System/Source: SUET Saat- und Erntetechnik GmbH/Germany



1.3 Structure of granulated seed–Example rape seed

The core of a granulated seed is the embryo. **Figure 5** depicts schematically the structural design of a granulated rape seed. The shell matrix containing fillers, minerals and SIPERNAT® specialty silica–indicated by the small white dots–is applied around the seed embryo by means of build-up granulation as described before. A coating consisting of an insecticide, fungicide in terms of a mordant can be chosen as an outer shell or applied directly on the seed. SIPERNAT® 22 was incorporated into the shell matrix in order to balance and enhance the water and nutrient supply that is limited through the shell matrix. Granulation improves the harvest and yield quality of the seed.

Figure 5
Structural design of granulated rape seed



The lower seed amount required per hectare combined with selective drilling (little or no seed loss by crushing) and the possibility to incorporate a protective fungicide or insecticide as coating are all advantages of seed granulation technology. Further benefits which lead to a more efficient cultivation of high value seeds are listed below.

Figure 6
Advantages of granulated/pelletized high value seeds

Advantages of using granulated / pelletized high value seeds

- Improved harvest and yield quality through better individual nutrient supply.
- Reduced application rate of pelletized seeds vs. untreated seed.
- Selective drilling without seed loss caused by crushing.
- Utilization of an insecticide or fungicide coating (mordant).
- Ideal nutrient and water supply through the use of micro nutrition ingredients.
- Possibility to include trace elements and fertilizers for advanced germination.
- Fortified root growth.
- Optimal planting of the seeds in the furrow and soil depth.

2 Seed granulation with SIPERNAT® specialty silica

Seed granulation technology can be applied to seeds that need to be precision sown to optimize yield and harvest quality. Hence it is especially interesting, besides other seeds, for the granulation of very small rape seed. However it needs to be assured that water and therewith the nutrition supply through the shell matrix into the growing seed embryo works properly. For this purpose SIPERNAT® specialty silica with its porous structure, its outstanding absorption properties, simultaneous high and constant product quality, and medium particle size has been approved for the use as a seed enhancer to be used in build-up granulation processes.

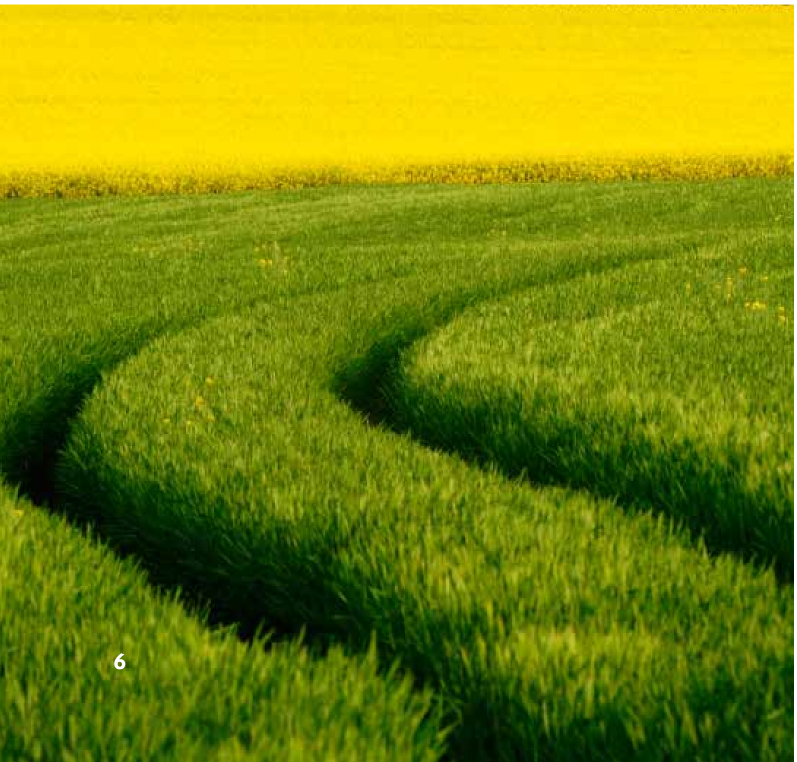
The most important physico-chemical product properties of SIPERNAT® 22 can be found in **Table 1** below.

Table 1
Characteristic physico-chemical properties of SIPERNAT® 22

Properties	Unit	Range**
Specific surface area N_2 Multipoint according to ISO 9277	m²/g	190
DOA*-Absorption (ISO CD 19246)[1]	ml/100 g	235
Particle size d_{50} Laser diffraction according to ISO 13320	µm	120
Loss on drying 2 h at 105 °C according to ISO 787-2	%	≤ 7
Loss on ignition[2] 2 h at 1000 °C according to ISO 3262-1	%	≤ 6.0
pH-value 5 % in water according to ISO 787-9	–	6.5
Tamped density (not sieved) according to ISO 787-11	g/l	260
SiO_2 content[3] according to ISO 3262-19	%	≥ 97

1 based on original substance
2 based on dry substance (2 h/105 °C)
3 based on ignited substance (2 h/1000 °C)
* Dioctyladipate

** The given data are typical values (no product specification) – specification on request



2.1 SIPERNAT® specialty silica for enhanced rape seed granulation - requirements

The granulation of highly valuable seeds requires not only adequate technical background knowledge and manufacturing equipment but also requirements regulated by the authorities and seed breeders must be fulfilled as well. As an example, the requirements for rape seed (in Germany) are illustrated in **Figure 7**. Besides the most important parameter, the germination rate after seven days (minimum 88 % according to the German Seed trading law / Saatgutverkehrsgesetz), the germination rate after storage is also very important. For biological reasons the water content of the granulated seeds have to fulfill a certain range. A target pellet size can be manufactured according to the individual machinery of the drilling equipment that is used for the precise sowing on the field.

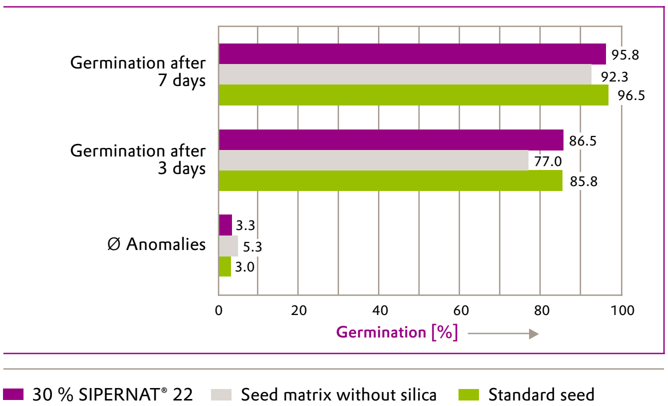
Figure 7
Requirements for the marketing of rape seed in Germany

Stability is a key parameter for the granules, as there is a risk that the pellets are crushed in sowing tools such as perforated discs for example. A certain pellet size need to be obtained by the granulation technology in order to avoid losses during the sowing. Depending on customer needs the pellet size can be adjusted during the build-up granulation process (see Chapter 1.2). The suitable size depends primarily on the seed size itself as well as on the amount of the seeds per hectare and not least on the hole size of the sowing disc.

2.2 Germination tests on laboratory basis

A common method to evaluate the germination performance of a granulated seed before introducing it into soil is a test series in the laboratory under defined growing conditions. In order to obtain comparable test results exactly 100 seeds are placed on a folded filter paper that simulates the nutrient medium in a plastic bowl. A defined amount of water is applied onto the seeds, the temperature is kept at 20 °C and a defined light exposure is implemented. The laboratory germination test is conducted for seven days with a first scoring after three days and a final evaluation after seven days of growth. The laboratory results of a fourfold determination of the germination of granulated rape seed is shown in **Figure 8**. The germination rate is calculated in percent (based on 100 planted seeds) and the number of anomalies is also given in percent.

Figure 8
Germination of rape seed – laboratory results



The test results show that the germination rate of granulated rape seed containing 30 % by weight SIPERNAT® 22 is on a comparable level to that of standard seed without any silica addition or shell matrix. However in contrast to untreated seed the germination behavior with SIPERNAT® 22 is on a higher level. Especially the rates of the first scoring measured after three days are significantly higher. All germination rates are able to fulfill the requirement of 88 % germination after a seven days growing period. Also the number of anomalies is on the same level with the seedlings containing SIPERNAT® specialty silica or the standard seed. Only the seedlings without SIPERNAT® 22 in the shell matrix show a slightly higher level of anomalies.

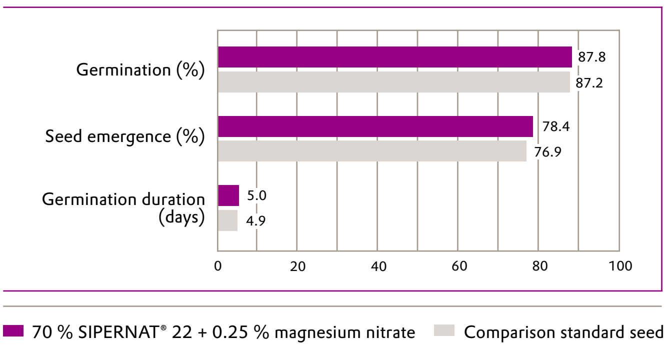
3 Field trials with SIPERNAT® specialty silica

While laboratory trials can indicate the germination behavior, the seed emergence and germination duration in the field are both very important. Therefore laboratory tests need to be repeated in the field under typical conditions. The results of field trials obtained for winter rape seed, spring rape seed, fodder radish and several kinds of mustard seed are listed comprehensively in the following. All field trials were conducted under the same conditions. In each trial 130 seedlings were planted into small plastic pots filled with potting compost using tweezers. As a control, 130 untreated standard seeds were potted in the same way. The seedlings were sprinkled with some water in order to keep the seedlings barely moist (up to three times a day). The trial was evaluated daily in the afternoon. All germinated plants with completed growth were counted and the germination rate and seed emergence were calculated in percent. The germination duration in days was also recorded. The trial was randomized and duplicated. All field trials described here were performed by DSV (Deutsche Saatveredelung AG / Germany) at their cultivation center "Hof Steimke" in Lower Saxony, Germany. The germination tests mentioned in Chapter 2.2 were carried out by SUET (Saat- und Erntetechnik GmbH/Germany) in their laboratory in Eschwege/Germany.

3.1 Winter rape seed (*Brassica Napus*)

The results of the field trial with winter rape seed (*Brassica Napus*) show that granulated and standard seeds had a comparable germination rate (see **Figure 9**). The grey bar represents the standard seed without a granulation matrix and the deep purple one demonstrates a granulated variation containing 70 % SIPERNAT® 22 and 0.25 % of a magnesium salt. The hygroscopic nature of magnesium salts is beneficial for the germination of winter rape seed.

Figure 9
Field trial with Winter Rape seed (*Brassica Napus*)

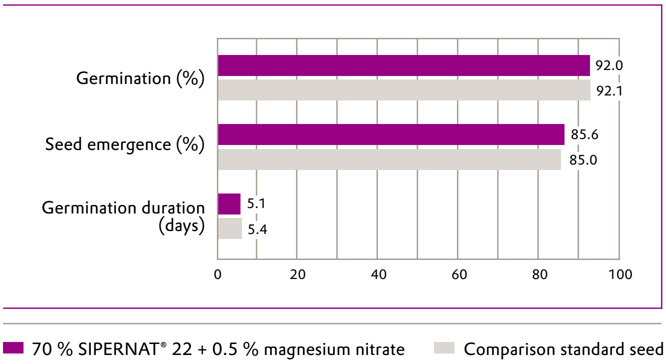


A slightly better germination behavior value was obtained with the granulated seed containing SIPERNAT® 22. In case of the seed emergence, an addition of SIPERNAT® 22 into the shell matrix is advantageous for enhanced water supply. However the germination duration is similar to that of pure standard seed. There is potential for improvement by the use of other hygroscopic salts or by adjusting concentrations. In general the unique porous structure of Evonik's SIPERNAT® grades is ideal for adsorbing salt solutions that need to be integrated in the powdered shell matrix for the granulation of highly valuable seeds. In combination with the enhancement of water supply this is a good example of the versatility of SIPERNAT® specialty silica in seed treatment applications.

3.2 Spring rape seed (*Brassica Napus*)

For spring rape seed (*Brassica Napus*) the results are completely comparable. However there are still many advantages to adding SIPERNAT® specialty silica into the shell matrix as mentioned in Chapter 1.3 **Figure 6**.

Figure 10
Field trial with Spring Rape seed (*Brassica Napus*)



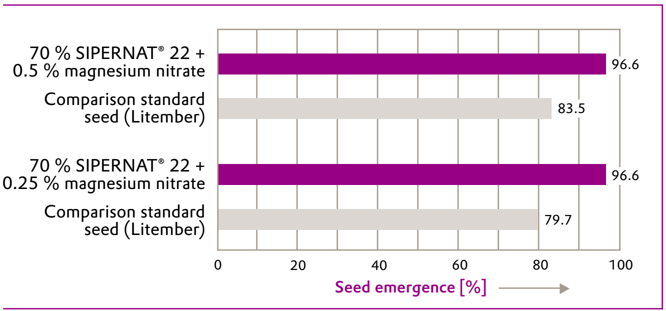
It should be noted that both the germination rate and the seed emergence are already on a very high level, around or above 92 % and 85 %, respectively. **Figure 10** shows the result of the test series with *Brassica Napus* (spring rape seed).

Especially compared to winter rape seed with a germination rate of around 87 % and much lower seed emergence, the higher values are obvious, indicating already very strong growth characteristics. In contrast to the trial with winter rape seed the concentration of magnesium nitrate added to the spring rape seed matrix was 0.5 %.

3.3 Mustard seed (*Sinapis Alba*)

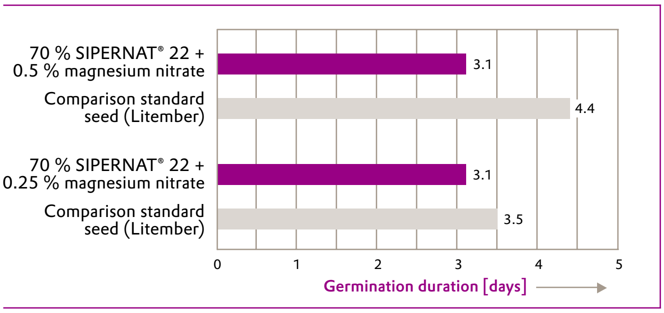
The addition of SIPERNAT® 22 in combination with magnesium nitrate as hygroscopic aid also showed a strong positive influence in the field test series with mustard seed (*Sinapis Alba*). The clear advantages are evident in the very high rates of seed emergence (c.f. **Figure 11**) observed as well as in short germination duration (c.f. **Figure 12**) compared to standard seed. The higher amount of SIPERNAT® 22 (in combination with magnesium nitrate) ensures a higher level of seed emergence (around 20 % higher compared to standard seed) and also shortens the germination duration up to 30 %.

Figure 11
Field trial with Mustard seed (*Sinapis Alba*)–Seed emergence



Thus the use of SIPERNAT® 22 contributes to an ideal water and nutrient supply during the growth phase of the mustard in the field in addition to the benefits of a lower seed amount to be sown and the possibility to apply a protecting insecticide coating or a fertilizing layer. All of which lead to an improved yield and harvest.

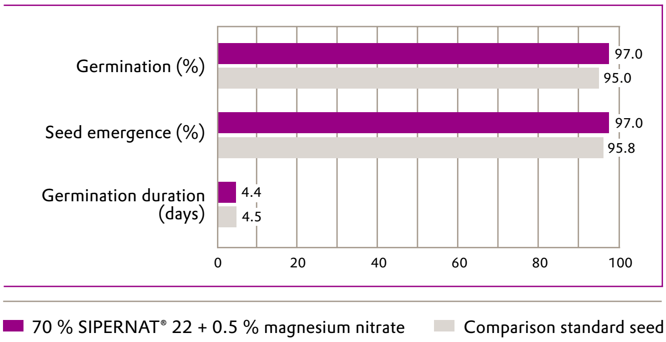
Figure 12
Field trial with Mustard seed (*Sinapis Alba*) – Germination duration



3.4 Fodder radish (*Raphanus Sativus*)

Another field trial was done with fodder radish (*Raphanus Sativus*). With regard to seed germination and emergence, a benefit can be observed for those seeds containing 70 % SIPERNAT® 22 and 0.5 % magnesium nitrate in the matrix. The addition of SIPERNAT® 22 also brings an advantage to the germination duration. All test results are shown in **Figure 13**.

Figure 13
Field trial with Fodder Radish (*Raphanus Sativus*)

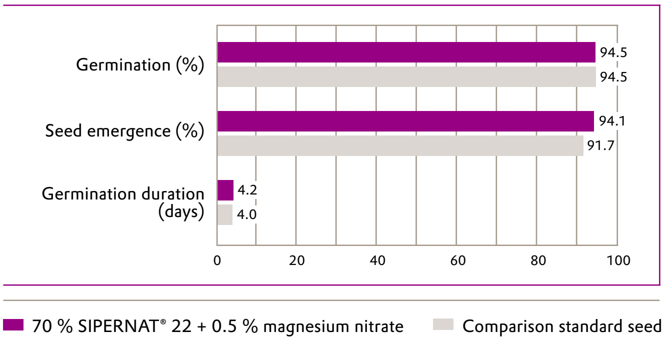


Also in this case the germination and seed emergence rates are on a comparatively high level.

3.5 White mustard (*Sinapis Alba*)

White mustard was also planted in the plastic pots filled with potting compost. While the germination rates of treated vs. untreated seeds are exactly the same (**Figure 14**), with regards to seed emergence the seeds containing SIPERNAT® 22 and 0.5 % magnesium nitrate are considerably better than those without. The germination duration of the granulated white mustard is on a slightly higher level.

Figure 14
Field trial with White mustard (*Sinapis Alba*)



These results indicate again that the advantages of seed granulation can be fully exploited without any risk of a reduced germination or significantly delayed germination duration. The water and nutrient supply can be secured and regulated by the use of SIPERNAT® 22. Thus the reduced germination rates in particular with rape seed (see Chapter 2.2) can be compensated for or even improved. These benefits are especially evident in the case of mustard seed (*Sinapis Alba*).

4 Seed granulation with SIPERNAT® specialty silica – examples, benefits and product overview

Besides the seeds mentioned before that were tested in the laboratory and the field regarding germination rate, seed emergence and germination duration, other seeds may also benefit when granulated and single – sowed. A small selection of suitable seeds can be found in **Table 2**.

Table 2 Selection of seed types suitable for seed granulation

Types of seed
- Winter rape seeds
- Grass seeds
- Fodder radish seeds
- Flower seeds
- Spring rape seeds
- Mustard seeds
- Vegetable seeds

The addition of SIPERNAT® 22 improves the water transport through the matrix of the granule resulting in an improved germination behavior. Especially when compared with conventional filler materials like minerals, stearate, clay or cellulose powder, SIPERNAT® 22 results in a superior germination. In general, the use of SIPERNAT® specialty silica within the granulation of high valuable seeds also imparts a unique particle size to the final granule as well as improving the granule hardness required for precise single sowing machines. The use of SIPERNAT® 22 can bring an assured germination value of at least 88 %, or even above 90 %, with spring and winter rape seed, mustard seed and fodder radish. A sufficient moisture content during storage can be obtained as well. A summary of the benefits of SIPERNAT® specialty silica when used as granulation aid is shown in **Figure 15**.

Other SIPERNAT® types with higher surface area or absorption capacity such as SIPERNAT® 50 or SIPERNAT® 350 are also possible to use. **Tables 3** and **4** show alternative products that could be used for seed granulation as well as their typical properties.

Figure 15
Benefits of SIPERNAT® specialty silica as granulation aid

Benefits of using SIPERNAT® specialty silica in granulated / pelletized seeds

- **Enhanced water transport from the silica matrix to the seed leads to an improved germination behavoir of the granulated seeds.**
- **Superior germination compared with natural-based products like minerals.**
- **Unique particle size due to granulation process and improved granule hardness.**
- **Assured germination value above 90 % and sufficient moisture content during storage with rape seed.**
- **Consistent product quality based on the constant quality of SIPERNAT® products.**
- **Technology is applicable for a broad range of seeds.**

Table 3
SIPERNAT® specialty silica and AEROPERL® products suitable for seed granulation

Other suitable types of silica
- SIPERNAT® 22
- SIPERNAT® 50
- SIPERNAT® 350
- SIPERNAT® 360
- AEROPERL® 300/30

Table 4
Properties of recommended hydrophilic and hydrophobic SIPERNAT® specialty silica grades and AEROPERL® product

Properties	Unit	SIPERNAT® 22	SIPERNAT® 50	SIPERNAT® 350	SIPERNAT® 360	AEROPERL® 300/30
Specific surface area N_2 Multipoint according to ISO 9277	m²/g	190	500	55	55	–
DOA-Absorption (ISO CD 19246)[1]	ml/100 g	235	305	170	195	–
Particle size d_{50} Laser diffraction according to ISO 13320	µm	120	50	4.5	18.5	approx. 30[4]
Loss on drying* 2 h at 105 °C according to ISO 787-2	%	≤ 7.0	≤ 7.0	≤ 7.0	≤ 7.0	≤ 3.5
Loss on ignition 2 h at 1000 °C[2] according to ISO 3262-1	%	≤ 6.0	5.0	≤ 6.0	≤ 6.0	≤ 2.5[5]
pH-value 5 % in water according to ISO 787-9	–	6.5	6.0	9.0	9.0	4.0 – 6.0[6]
Tamped density* not sieved according to ISO 787-11	g/l	260	180	120	180	approx. 280
SiO_2 content[3] according to ISO 3262-19	%	≥ 97	≥ 97	≥ 97	≥ 97	–

[1] based on original substance
[2] based on dry substance (2 h/105 °C)
[3] based on ignited substance (2 h/1000 °C)
[4] average particle size
[5] Ignition loss; 2 hours at 1000 °C, based on material dried for 2 hours at 105 °C
[6] pH; in 4 % dispersion
* ex plant

The data represents typical values (no product specification) – specifications on request

5 SIPERNAT® specialty silica and AEROSIL® fumed silica in seed coatings

Besides the use of SIPERNAT® specialty silica as an effective additive that regulates the water and nutrient supply in a seed matrix to be used for the seed granulation it can also be applied as a hydrophobic additive in a solid or liquid seed coating formulation. In addition to its use as a moisture protecting barrier AEROSIL® fumed silica offers a rheology modifying function that is the basis for the stabilization of water and oil based insecticide or fungicide seed coatings as well as pigments added therein.

AEROSIL® fumed silica can help to achieve the following formulation properties crucial in liquid seed coatings

- stable formulation with homogeneously dispersed active ingredients
- medium viscosity level that prevents AI/pigment settling or re-agglomeration
- good pourability respectively sprayability
- good adhesion on the seed granule or seed surface
- simplified package cleaning is crucial for liquid seed coatings

The incorporation of AEROSIL® fumed silica stabilizes the system to allow long term storage stability.

5.1 Liquid seed coatings

The improvement of the stability and thus the efficiency of a liquid seed coating containing insecticides or fungicides is related to the prevention of AI/pigment settling that occurs during storage, especially at higher temperatures. AEROSIL® fumed silica helps to achieve a perfect balance between a moderate yield point (viscosity level at rest) on the one hand and a low shear viscosity whilst spraying on the seeds on the other hand. The stabilizing effect of AEROSIL® fumed silica is achieved through a reversible three-dimensional loose but elastic network that is generated by an interaction of the silanol groups located on the surface of the silica aggregates. During storage the viscosity level and therewith the yield point is higher but upon applying mechanical stress (e.g. whilst stirring or shaking) the temporary structure breaks down causing e.g. the viscosity to decrease – the so-called shear thinning effect. Due to the reversibility of the system the viscosity level builds up again in the next resting phase. The use of AEROSIL® fumed silica gives clear benefits, in particular if storing or shipping the seed coating formulation at higher temperatures.

Figure 16
Hydrophobic AEROSIL® fumed silica in corn oil stored for three days and measured at RT

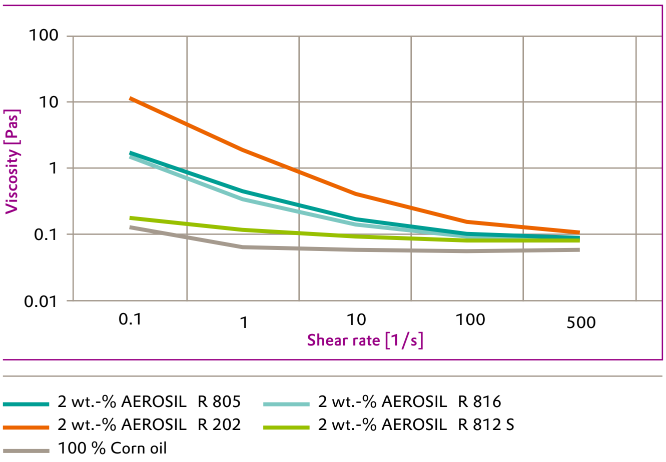
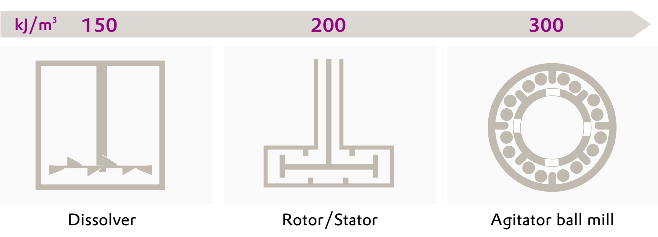


Figure 16 illustrates the excellent thickening properties of various types of hydrophobic AEROSIL® fumed silica in corn oil. An addition of just 2 % AEROSIL® R 202 increases the viscosity to around one-hundred times higher than that of the pure corn oil. Depending on the customer's need, lower and medium viscosity levels can be tailored using other AEROSIL® grades and by adjusting the silica concentration. As a rough rule of thumb, concentrations of AEROSIL® fumed silica between 2 and 5 % are suitable to obtain a good anti-settling effect.

The use of adequate dispersion equipment whilst incorporating AEROSIL® products is crucial to obtain the desired viscosity levels. The energy input into the liquid is the decisive factor. On the one hand too high shear forces may damage the structure of the AEROSIL® fumed silica that is the basis for the network building characteristics; on the other hand, too low shear intensity may lead to a poor distribution of the silica particles in the liquid and additionally to insufficient wetting. Suitable devices for dispersing AEROSIL® products are high speed mixers such as dissolvers, rotor-stator mixers or bead mills. The user must keep in mind the differences in the energy input on the system generated by the different dispersing devices.

Figure 17
Possible energy input of different dispersing devices



The energy input increases beginning with the dissolver, increasing over rotor-stator systems, followed by a bead mill as depicted in **Figure 17**. If longer dispersing or milling times are needed – for example to mill down an added active ingredient – the order of addition has to be adjusted and the right type of AEROSIL® fumed silica has to be chosen.

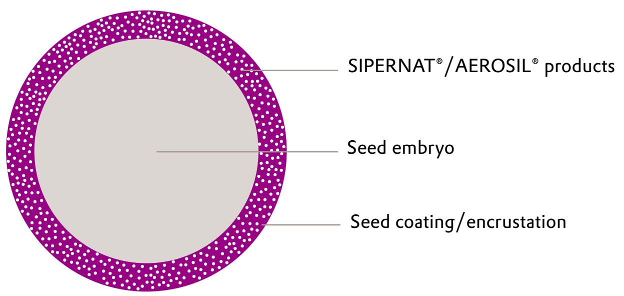
In general the dispersing time and the rotational speed need to be adapted considering the type of AEROSIL® fumed silica as well as the application itself. Usually the dispersion of AEROSIL® products with a higher surface area, e.g. AEROSIL® 300, AEROSIL® 380 or AEROSIL® R 812 S, requires a longer dispersion time or a higher rotational speed (if using a dissolver system). If using a dissolver or rotor-stator system the peripheral velocity can be more than 7 m/sec. For most industrial applications we suggest tip speeds ranging from 8–10 m/s in order to insure an adequate shear.

In the case of a bead mill, a tip speed of 4.6 m/s (at a ratio of blade to vessel diameter of 1 : 2 to 1 : 3) should be applied for a shorter dispersing time of around 10 minutes. A stepwise addition of AEROSIL® fumed silica along with a pre-dispersion at a rotation speed of 500 rpm is recommended. It is advisable that the incorporation of AEROSIL® fumed silica should be the last step of the manufacturing process. Air bubbles incorporated during the dispersion process should be removed by vacuum. The incorporation of AEROSIL® fumed silica can be carried out at room temperature and without the addition of an activator.

5.2 Solid seed coatings

The addition of hydrophobic AEROSIL® or SIPERNAT® products into a special coating formulation, for example in the outer shell of a seed embryo or also as layer onto the shell, offers certain functionalities and benefits . This is especially advantageous when the uneven or furrowed structure of the seed surface makes a regular seeding difficult or reduces seed flowability. One main function of our silica products is helping to smoothen the seed surface resulting in an improvement of the flow characteristics. **Figure 18** depicts the structure of encrusted seed.

Figure 18
Structural design of encrusted seed containing SIPERNAT® and AEROSIL® products



Hydrophobic AEROSIL® and SIPERNAT® products can be used as a moisture barrier directly in the solid seed coating in order to prevent a rapid penetration of moisture that could harm the seeds' growth. The hydrophobic–water repellent–nature provides a protective layer when incorporated in the shell matrix or the coating of the seeds. Seeds that are water sensitive or susceptible to mold are thus protected. It is also possible to create a slow moisture uptake by adapting concentration of AEROSIL® and SIPERNAT® products to the desired protection level.

The use of both hydrophobic and hydrophilic silica products as free flow agent leads to a spacer effect between the seeds and thus to improved flow characteristics. A good flowability is the prerequisite if encrusted seeds need to be transported during drilling and automated packaging. Due to the hydrophilic nature of some SIPERNAT® grades and their unique absorption capacity a twofold advantage can be obtained. Firstly, addition leads to an improvement of the flowability and secondly, the silica accelerates drying as a highly absorptive ingredient in the outer shell of a seed grain. A third functionality is also related to the high absorption capacity of SIPERNAT® specialty silica: its use as a carrier for potentially sticky or highly viscous insecticide- or fungicide formulations to be incorporated into the solid seed coating. The combination of silica carrier products with a corresponding coating material opens up the possibility to create a slow release of the carried active ingredient.

An overview of EVONIK's portfolio of AEROSIL® and SIPERNAT® products for liquid and solid seed coatings can be found in the following chapter.

6 Selection of SIPERNAT® and AEROSIL® products for seed coatings

A selection of recommended types of AEROSIL® and SIPERNAT® grades and examples for their uses in the field are given in the tables below. Please contact us for more specific and detailed information as well as to request samples.

Table 5
Application fields of seed coatings

Your application
• Insecticide coating
• Fungicide coating
• Seed mordant
• Moisture control
• Biocides

Table 6
Selection of suitable AEROSIL® and SIPERNAT® grades

Suitable types of silica
AEROSIL® 200
AEROSIL® 300
AEROSIL® 380
AEROSIL® COK 84
AEROSIL® R 816
AEROSIL® R 972
AEROSIL® R 974
AEROSIL® R 805
AEROSIL® R 812 S
AEROSIL® R 202
SIPERNAT® 22 S
SIPERNAT® 50 S
SIPERNAT® D 17

7 Product overview for seed coatings

Table 7
Properties of recommended hydrophilic AEROSIL® fumed silica, AEROXIDE® fumed aluminum oxide and AEROSIL® mixed oxide grades

Properties	Unit	AEROXIDE® Alu C	AEROSIL® 200	AEROSIL® 300	AEROSIL® 380	AEROSIL® COK 84
Specific surface area, (BET) method ISO 9277	m^2/g	100 ± 15	200 ± 25	300 ± 30	380 ± 30	185 ± 30
pH value, 4 % in water method ISO 787-9		4.5 – 5.5	3.7 – 4.5	3.7 – 4.5	3.7 – 4.5	3.6 – 4.3
Loss on drying[1], 2 h at 105 °C method ISO 787-2	wt. %	≤ 5.0	≤ 1.5	≤ 1.5	≤ 2.0	≤ 1.5
Loss on ignition, Based on dry substance 2 h at 1000 °C method ISO 3262-20	wt. %	≤ 3.0	≤ 1.0	≤ 2.0	≤ 2.5	≤ 1.0
Tamped density[1], (approximate value) method DIN ISO 787/11, Aug. 1983	g/l	appr. 50	50	50	50	50
SiO_2 content, (based on ignited substance) method ISO 3262-20	wt. %	≥ 99.8[2]	≥ 99.8	≥ 99.8	≥ 99.8	82 – 86[3]

[1] ex plant [2] Al_2O_3 content: Pure aluminum oxide [3] Al_2O_3 content: 14 – 18 %

The data represents typical values (no product specification) – specifications on request

Table 8
Properties of recommended hydrophilic and hydrophobic SIPERNAT® specialty silica grades

Properties	Unit	SIPERNAT® 22 S	SIPERNAT® 50 S	SIPERNAT® D 17
Specific surface area N_2 Multipoint according to ISO 9277	m^2/g	190	500	–
DOA-Absorption (ISO CD 19246)[1]	ml/100 g	240	290	–
Particle size d_{50}, Laser diffraction according to ISO 13320	µm	13.5	18	10.0
Loss on drying *, 2 h at 105 °C according to ISO 787-2	%	≤ 7.0	≤ 7.0	≤ 6.0
Loss on ignition, 2 h at 1000 °C[2] according to ISO 3262-1	%	≤ 6.0	≤ 6.5	≤ 6.0
pH-value, 5 % in water according to ISO 787-9	–	6.5	6.0	8.0
Tamped density *, not sieved according to ISO 787-11	g/l	90	105	150
SiO_2 content[3], according to ISO 3262-19	%	≥ 97	≥ 97	≥ 97
Wettability by methanol, (internal method)	%	–	–	≥ 52
Carbon content, method ISO 3262-19	%	–	–	1.7

[1] based on original substance [2] based on dry substance (2h/105 °C) [3] based on ignited substance (2h/1000 °C) * ex plant

The data represents typical values (no product specification) – specifications on request

Table 9
Properties of recommended surface treated AEROSIL® fumed silica grades

Properties	Unit	AEROSIL® R 202	AEROSIL® R 812 S	AEROSIL® R 972	AEROSIL® R 974	AEROSIL® R 805	AEROSIL® R 816
Specific surface area, (BET) method ISO 9277	m^2/g	100 ± 20	220 ± 25	110 ± 20	170 ± 20	150 ± 25	190 ± 20
pH value, 4 % in water method ISO 787-9		4.0 – 6.0	5.5 – 7.5	3.6 – 5.5	3.7 – 4.7	3.5 – 5.5	4.0 – 5.5
Carbon content, method ISO 3262-20	wt. %	3.5 – 5.0	3.0 – 4.0	0.6 – 1.2	0.7 – 1.3	4.5 – 6.5	0.9 – 1.8
Loss on drying[1], 2 h at 105 °C method ISO 787-2	wt. %	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5	≤ 1.0
Loss on ignition, Based on dry substance 2 h at 1000 °C method ISO 3262-20	wt. %	4.0 – 6.0	1.5 – 3.0	≤ 2.0	≤ 2.0	5.0 – 7.0	not determined
Tamped density[1], (approximate value) method DIN ISO 787/11, Aug. 1983	g/l	60	60	50	50	60	60
SiO_2 content, (based on ignited substance) method ISO 3262-20	wt. %	≥ 99.8	≥ 99.8	≥ 99.8	≥ 99.8	≥ 99.8	≥ 99.8

[1] ex plant

The data represent typical values (no product specification) -specifications on request

8 Literature

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Europe / Middle-East / Africa / Latin America

Evonik Resource Efficiency GmbH
Business Line Silica
Rodenbacher Chaussee 4
63457 Hanau
Germany

PHONE +49 6181 59-12532
FAX +49 6181 59-712532

ask-si@evonik.com
www.evonik.com

North America

Evonik Corporation
Business Line Silica
299 Jefferson Road
Parsippany, NJ 07054-0677
USA

PHONE +1 800 233-8052
FAX +1 973 929-8502

ask-si-nafta@evonik.com

Asia Pacific

Evonik (SEA) Pte. Ltd.
Business Line Silica
3 International Business Park
#07-18, Nordic European Centre
Singapore 609927

PHONE +65 6809-6877
FAX +65 6809-6677

ask-si-asia@evonik.com

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