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RICE SEED TREATMENT AND RECOATING WITH POLYMERS: PHYSIOLOGICAL QUALITY AND RETENTION OF CHEMICAL PRODUCTS[1]

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ABSTRACT - The use of chemical seed treatment is an important tool in the protection of seedlings and has contributed to the increase of rice yield (*Oryza sativa* L.). The objective of this study was to evaluate the physiological quality and quantify the retention of chemical products in rice seeds treated with insecticide and fungicide coated with polymers. Six seed treatments were used: control, phytosanitary treatment and phytosanitary treatment and coating with the polymers, Florite 1127®, GV5® Solid Resin, Polyseed CF® and VermDynaseed®. The physiological quality was evaluated by the test of germination and vigor by first count tests, germination speed index, shoot length, radicle length, seedling dry mass and sand emergence. To determine the retention of the active ingredients metalaxyl-M and thiamethoxam, an equipment called extractor was used. The experiment was organized in a completely randomized design (DIC) and the averages were separated by the Scott Knott test ($p \leq 0.05$). Seed treatment with the fungicide and insecticide, coated with the polymers, Florite 1127®, Solid Resin GV5®, Polyseed CF® and VermDynaseed®, did not affect the physiological quality of rice seeds. Solid Resin GV5®, Polyseed CF® and VermDynaseed® polymers were efficient at retaining thiamethoxam in the rice seeds, preventing some of the active ingredients of the insecticide from being leached through the sand columns immediately after the simulated pluvial precipitation.

Keywords: *Oryza sativa*. Germination. Vigor. Thiamethoxam. Leaching.

TRATAMENTO DE SEMENTES DE ARROZ RECOBERTAS COM POLÍMEROS: QUALIDADE FISIOLÓGICA E RETENÇÃO DE PRODUTOS QUÍMICOS

RESUMO - O uso do tratamento químico de sementes é uma importante ferramenta na proteção de plântulas e tem contribuído com a elevação da produtividade de arroz (*Oryza sativa* L.). Objetivou-se avaliar a qualidade fisiológica e quantificar a retenção de produtos químicos em sementes de arroz tratadas com inseticida e fungicida recobertas com polímeros. Foram utilizados seis tratamentos de sementes: controle, tratamento fitossanitário e tratamento fitossanitário e recobrimento com os polímeros, Florite 1127®, Resina Sólida GV5®, Polyseed CF® e o VermDynaseed®. A qualidade fisiológica foi avaliada pelo teste de germinação e vigor pelos testes de primeira contagem, índice de velocidade de germinação, comprimento de parte aérea, comprimento de radícula, massa seca de plântulas e emergência em areia. Para determinar a retenção dos ingredientes ativos metalaxil-M e thiamethoxam, utilizou-se equipamento denominado extrator. O experimento foi organizado no delineamento inteiramente casualizado (DIC) e as médias foram separadas pelo Scott Knott ($p \leq 0,05$).O tratamento de sementes com o fungicida e inseticida, recobertos com os polímeros,Florite 1127®, ResinSolid GV5®, Polyseed CF® e o VermDynaseed®, não afetaram a qualidade fisiológica de sementes de arroz. Os polímeros ResinSolid GV5®, Polyseed CF® e o VermDynaseed® foram eficientes na retenção do thiamethoxam junto às sementes de arroz, impedindo que parte do ingrediente ativo do inseticida fosse lixiviado, através das colunas de areia, logo após a precipitação pluvial simulada.

Palavras-chave: *Oryza sativa*. Germinação. Vigor. Thiamethoxam. Lixiviação.

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INTRODUCTION

The irrigated rice crop is concentrated in the southern states of Brazil, and Rio Grande do Sul and accounts for almost 70% of the national production. The average productivity of the state of Rio Grande do Sul has increased in the last decades, stabilizing in recent years, with average levels above 7,000 kg ha^{-1} (CONAB, 2015).

Chemical seed treatment is an important tool for seedlings protection in the initial stages of crop development (MARCOS FILHO, 2015). There has been an evolution in the chemical industry, with the introduction of fungicides and systemic-acting insecticides since the 1990s. This has contributed to improved rice yields, and the indiscriminate use of chemicals can cause resistance to organisms, target non-target organisms and contaminate the water table (SHARMA et al., 2015).

The loss of chemicals to the environment occur in a variety of ways, including the leaching process, which refers to the potential by which chemical compounds travel through the soil profile via rainwater or irrigation (CASTRO et al., 2008). This process is dependent on the physico-chemical properties of the soil and products, environmental conditions, soil management practices and the product application (MILHOME et al., 2009). Thiamethoxam, which is the active ingredient of insecticides of the neonicotinoids group (used in the treatment of rice seeds), has low sorption in the soil and high solubility in water, characteristics that facilitate its leaching (BANERJEE et al., 2008).

The use of polymers associated with the chemical treatment of seeds is a promising technique for use in agriculture, promoting better adhesion of the products to the seeds, minimizing the contamination of man and the environment by reducing dust, and preventing the leaching of chemical products (TIWARI et al., 2011; AVELAR et al., 2012; VINODKUMAR et al., 2013; KEAWKHAM et al., 2014; AVELAR et al., 2015). Studies using this association demonstrated that there was no interference in the physiological quality of seeds of several agricultural species, such as cotton (LIMA et al., 2006), maize (BENATTO JUNIOR et al., 2012; AVELAR et al., 2015), and rice (CASTAÑEDA et al., 2014).

Studies (information) that quantify the retention of chemical products in rice seeds when coated with polymers is scarce. Thus, the objective was to evaluate the physiological quality and quantify the retention of chemical products in rice seeds treated with insecticide and fungicide coated with polymers.

MATERIAL AND METHODS

This study was conducted at the Laboratory of Seed Research (LDPS), and at the Laboratory of Analysis of Residues and Pesticides (LARP) belonging to the Federal University of Santa Maria (UFSM). Seeds of irrigated rice, cultivar BRS Sinuelo CL® (EMBRAPA), adapted for cultivation in the state of Rio Grande do Sul, were used.

The seeds were initially characterized by the germination test and vigor by the first count tests, germination speed index, shoot length, radicle length, dry mass of seedlings, moisture and weight of one thousand seeds (BRASIL, 2009a). For the phytosanitary treatment, the commercially available fungicide Maxim XL® (ia: metalaxyl-M 25 g L^{-1} + fludioxonil 10 g L^{-1}) was used at a dose of 3 mL kg $^{-1}$ for the product associated with the insecticide Cruiser 350® FS (i.e. thiamethoxam 350g L^{-1}) at a dose of 4ml kg^{-1} of the commercial product. After the phytosanitary treatment, the seeds were covered by the following polymers: Florite 1127®, at a dose of 3 mL kg^{-1} of seed; Solid Resin GV5® at a dose of 2 mL kg^{-1} seed; Polyseed CF® (Rigrantec) at a dose of 0.4 mL kg^{-1} of seed; and the Dynassed® DAC-BTE Red (Dynatech) at a dose of 3 mL kg^{-1} of seed. To form the syrup, 10 mL kg^{-1} of distilled water/ seed was added, and then applied to the seeds in plastic bags with a capacity of three liters, followed by agitation for proper homogenization. After this procedure, the treated seeds were allowed to stand for 24 h and were exposed in a naturally ventilated environment for drying. For comparison criteria, the seeds that were used for the control did not receive any chemical treatment and polymers.

In this study, six treatments were used: control, phytosanitary treatment with fungicide and insecticide (Trat Fito), Trat Fito + Florite 1127®, Trat Fito + Solid Resin GV5®, Trat Fito + Polyseed CF®, Trat Fito + VermDynaseed®.

Thereafter, the seed treatments (pre-leaching) were evaluated by means of the following tests:

A) Germination test – It was conducted by sowing 50 seeds in the monitor, distributed in two sheets of filter paper, moistened with distilled water in the ratio 2.5 times the dry paper weight (BRASIL, 2009a). After seeding, the rolls of paper were packed in plastic bags and placed in the Biochemical Oxygen Demand type of biological development chamber (B.O.D.) at 25°C. The evaluation was carried out at 14 days after sowing, and the results were expressed as the mean percentage of the normal seedlings (seedlings without deformities, in a good condition, which had the size of the radicle and shoot size greater or equal to the seed length).

B) First counting test and germination velocity index (GVI) were carried out together with the germination test. In the first count, the evaluation of the percentage of vigorous normal seedlings was evaluated on the fifth day after the test, as recommended by Brasil (2009a). For GVI, normal seedlings were counted daily at the same time until the 14th day, according to Maguire (1962) edited by Nakagawa (1999).

C) Test of shoot length, root length and seedling mass for these tests were performed on two lines mismatched in the upper third of the filter paper, containing 20 seeds in eight replicates and stored in BOD at 25°C, for five days. The average length of the shoot and radicle were obtained on the fifth day from measurements of 10 normal seedlings, using a millimeter ruler. After seedling measurements, these were placed in paper bags, kept in an oven at 60 ± 5°C, until a constant dry mass (48 h) was obtained and weighed on a precision scale (0.001 g). The results were expressed in millimeters and milligrams (mm and mg seedling^{-1}) according to Nakagawa (1999).

D) Test of sanity in filter paper seeds were evaluated through the "Blotter Test" (BRASIL, 2009b), being sown eight replicates of 25 seeds distributed in "gerbox" type boxes. Seed germination was inhibited by the freezing method for 24 h (BRASIL, 2009b), and after the seventh day of sowing, the percentage of fungi was evaluated with the aid of the specialized bibliography of Barnett and Hunter (1998).

To perform the leaching and to quantify the retention of fungicide and insecticide in rice seeds covered by polymers, an equipment called "Extractor" was set up. It consisted of three wooden supports with a height of 0.18 m, which supported a wooden board in the horizontal position measuring 1.27 m x 0.20 m. In this table, with 12 holes, spaced 0.05 m from each other, the PVC pipes, with 0.15 m height and 0.04 m internal diameter, were coupled. The PVC tubes were first waxed, to create a hydrophobic layer, closed in the bottom with a net of tulle and filter paper, and tied with ties. They were filled up to 0.10 m high, with washed and sterilized sand that passed through a one-millimeter sieve (FIRMINO et al., 2008). After saturation of the sand with distilled water, 100% of the retention capacity was made (BRASIL, 2009a). Thereafter, five seeds were sown in each tube, with four replicates of each treatment forming 24 experimental units. After sowing, a pluvial precipitation equivalent to 50 mm was simulated for 10 min, corresponding to 84 mL of distilled water added over the sowing area. The water flowed through the PVC column and the leachate was collected in glass bottles inserted below each tube.

In order to quantify Metalexil-M and Thiamethoxam, the leachate containing flasks were taken to the LARP, the detection was with the aid of Ultra Efficiency Liquid Chromatography Coupled to Mass Spectrometry in series (Ultra-High Performance Liquid Chromatography (UHPLC-MS / MS)) with a detection limit of 0.75 µg L^{-1} and quantification of 0.25 µg L^{-1} (KEMMERICH et al., 2014).

In the LDPS, the set of extractors was conditioned in a room with constant light and temperature of 25°C, for a period of 14 days for the evaluation of the rice seedlings. On the 14th day, the emergence, root length, shoot length and seedling dry mass were evaluated.

For the analysis of pre-leaching and post-leaching experiments, the treatments were arranged in a completely randomized design (DIC). The data were tested by means of normality assumptions of the errors and homogeneity of variances, and when necessary, the transformation. After ANOVA, the means were compared by the Scott Knott test ($p \leq 0.05$), using the Sisvar software (FERREIRA, 2011).

RESULTS AND DISCUSSION

The seed lot of the cultivar BRS Sinuelo CL ® is presented as the initial characterization, the weight of one thousand seeds of 26.58 g and humidity percentage of 11%. The germination was 88% and the vigor as evaluated by the first count test was 84% (Table 1, control).

By analyzing the results found for germination (G), vigor (PC), Germination Velocity Index (GVI) and seedling dry matter (DM) before leaching, it was verified that there were no significant differences between seed treatments (Table 1). These results qualify the polymers used, since one of the criteria for the materials used as seed coat film is that they do not react negatively with the chemicals and do not affect the physiological quality (ROY et al., 2014), thereby corroborating the results found by Castañeda et al. (2014), Keawkham et al. (2014) and Melo et al. (2015), where no changes were observed in the physiological potential of rice seeds and other agricultural species when they were treated with phytosanitary and polymer coatings. For soybean seeds, Verma and Verma (2014) considered the benefits of the association and compatibility of the polymer material with the fungicide, resulting in higher percentages of germination.

The GVI is one of the methods used to evaluate seed vigor, because the faster they germinate, the more vigorous they will be and with greater uniformity will they form the seedling stand. However, this variable was not affected by the treatments of seeds, not emphasizing the beneficial effect of the polymer coating on regular acceptance, in the same way as Evangelista et al. (2007) observed in soybean seeds.

On the other hand, in the tests of aerial part length (CPA) and radicle (CR) there were significant differences among the treatments (Table 1), presenting higher values for the control. In this case, it is possible that the chemical treatment caused a phytotoxic effect on the initial seedling growth, as mentioned by Ludwig et al. (2014) in sowing of cambre seeds, using the substrate filter paper, in which the coating of chemically treated seeds with polymers, potentiated the action of the insecticide and fungicide causing damage to germination under laboratory conditions.

Table 1. Average germination (G,%), first count (PC,%), germination velocity index (GVI), shoot length (CPA, mm plant^{-1}), length of primary root, Plant^{-1}) and the dry matter (DM, mg plant^{-1}) of rice seeds (BRS Sinuelo) (Trat fito = Phytosanitary treatment).

Seed Treatment	G[1]	PC[1]	GVI[1]	CPA[1]	CR[1]	MS[1]
Control	88 a	84 a	10 a	21 A	75 a	24 a
Tratfito	92 a	81 a	9 a	15 C	66 b	23 a
Tratfito + FloRite 1127®	90 a	84 a	9 a	18 B	65 b	23 a
Tratfito + Solid Resin GV5®	93 a	85 a	9 a	17 B	63 b	23 a
Tratfito+ Polyseed CF®	91 a	85 a	10 a	17 B	64 b	23 a
Tratfito+ VermDynaseed®	90 a	87 a	10 a	17 B	58 c	23 a
CV (%)	4.52	4.89	5.66	7.59	6.75	3.29

[1]Averages not followed by the same letter in the column, differ by the Scott-Knott test at the 5% probability level.

In the sanitary analysis (Table 2) were found fungi, some of them as *Fusarium* sp. (40%), *Aspergillus* sp. (1%) and *Dreschlera* sp. (9.5%). The use of phytosanitary treatment, associated or not to polymers, was effective in the control of fungi present in the seeds, preserving their sanitary quality, without compromising the expression of vigor in the first count test (Table 1). Especially those fungi that cause disease in rice such as *Fusarium* sp. and *Dreschlera* sp.

Table 2. Percentage of fungi found in rice seeds (BRS Sinuelo CL), submitted to seed treatment (Trat fito = Phytosanitary treatment).

Seed treatment	*Fusarium* sp.[1, 2]	*Penicillium* sp.[1, 2]	*Aspergillus* sp.[1, 2]	*Dreschlera* sp.[1, 2]
Control	40 a	0.0 a	1.0 a	9.5 a
Tratfito	11 b	0.0 a	0.7 a	0.0 b
Trat fito+ Florite 1127®	7.5 b	0.0 a	0.7 a	0.0 b
Tratfito+ Solid Resin GV5®	10.5 b	0.0 a	0.7 a	0.0 b
Tratfito+ Polyseed CF®	9.5 b	1.0 a	0.5 a	0.0 b
Tratfito+ VermDynaseed®	12 b	0.5 a	0.9 a	0.0 b
CV(%)	43.43	27.29	27.29	32.69

[1]Types not followed by the same letter in the column, differ by Scott-Knott test at the 5% probability level. [2]For the analysis, the data transformation was performed for $\sqrt{x+1}$.

The results from the evaluation of the seed treatments, which were sown in the sand tubes, after the leaching process, are presented in Table 3.

Although the active ingredient thiamethoxam, retained in the seeds after the leaching process, was not present in the control treatment and was in minor concentration as a result of losses in the phytosanitary treatment (Table 4), there were no statistical differences between the treatments with respect to the variable vigor EM, CPA, CPR and MS) (Table 3). Seeds with high initial vigor at sowing were used and it was carried out under controlled conditions of temperature, humidity and substrate free from phytopathogenic organisms. These data corroborate the study of Trentini et al. (2005) in which they used good-quality soybean seeds treated with the Tegram® fungicide and coated with the AGL 205® polymer when exposed to a favorable environment for rapid and uniform emergence, no significant differences were found for the variables studied between the Control treatment and the fungicide and polymers combination. Thus, it is possible that the benefits of using polymers may be better expressed under uncontrolled conditions.

Table 3. Emergence (EM, %), shoot length (CPA, mm), primary root length (CR, mm) and dry mass (MS, mg) of rice seedlings (BRS Sinuelo) cultivated in PVC pipes, after leaching. (Trat fito = Phytosanitary treatment).

Seed treatment	EM[1]		CPA[1]		CR[1]		MS[1]	
Control	80	A	48	a	79	a	24.30	a
Trat fito	90	A	54	a	81	a	22.93	a
Trat fito+ Florite 1127®	90	A	53	a	77	a	23.08	a
Trat fito+ Solid Resin GV5®	95	A	57	a	104	a	23.16	a
Tratfito+ Polyseed CF®	100	A	54	a	93	a	23.70	a
Tratfito+ VermDynaseed®	80	A	55	a	89	a	24.31	a
CV(%)	7.13		7.91		9.08		3.31	

[1]Averages not followed by the same letter in the column differ from the Scott-Knott test at the 5% probability and data transformation level for $\sqrt{x+1}$

Table 4. Thiamethoxam concentration in leachate samples, using the UHPLC-MS / MS technique, carried out at the Laboratory of Analysis of Residues and Pesticides (LARP / UFSM) (Trat fito = Phytosanitary Treatment).

Seed treatment/I.A	Thiamethoxam (μg L^{-1})[1]*	
Control	n.d[2]	
Trat fito	1522.62	A
Trat fito+ Florite 1127®	1675.97	A
Trat fito+ Solid Resin GV5®	937.10	B
Tratfito+ Polyseed CF®	1041.27	B
Tratfito+ VermDynaseed®	1028.02	B
CV(%)	18.72	

[1]Averages not followed by the same letter in the column, differ by the Scott-Knott test at the 5% probability level. [2]n.d: not detected and not quantified by the method employed. *Initial mean dose of i.a thiamethoxam applied to seeds: 2214.28 μg L^{-1}.

The results of the thiamethoxam i.a concentration (μg L^{-1}) detected by the UHPLC-MS / MS technique in the leachate samples are shown in Table 4. The i.a metalaxyl-M concentration data present on the fungicide were not (0.25 μg L^{-1}) and quantification (0.25 μg L^{-1}) of the method used for extraction (KEMMERICH et al., 2014). There were differences between the treatments, benefiting the combinations Trat fito + Solid Resin GV5®, Trat fito + Polyseed CF® and Protein + VermDynaseed®, which were more efficient in the retention of i.a thiamethoxam in rice seeds. Part of the ai was leached, thereby differing from the phytosanitary treatment and Trat fito + Florite 1127® that recorded the highest concentrations of thiamethoxam in the leachate.

It was observed (Table 5) that the seeds treated with fungicide and insecticide without coating with the polymers (Phytosanitary Treatment) were protected with only 31% of the initial dose of i.a thiamethoxam applied to the seeds (691.66 μg L^{-1}) and the other 69% (1522.62μg L^{-1}) was leached from the sand column. However, the polymer association, Solid Resin GV5®, Polyseed CF®, Red Dynaseed® and i.a thathiomethoxam resulted in a lower percentage of leach losses (42, 47 and 46%, respectively) and a higher percentage of thiamethoxam together (58, 53 and 54%, respectively). The use of Solid Resin GV5®, Polyseed CF®, and Red Dynaseed® polymers in chemical treatment subjects contributed 27, 22 and 23% more thiamethoxam to protect seeds against pest attack in the early stages of rice development. Also, it prevented a percentage of thiamethoxam from being lost by the leaching process when compared to the use of phytosanitary treatment alone. These polymers were efficient in promoting greater adhesion of the chemical to rice seeds.

Table 5. Concentration of the active ingredient of the insecticide - i.a. Thiamethoxam (five rice seeds) before leaching, in the leachate and after leaching. (Trat fito = Phytosanitary treatment).

Rice Seed treatment / Average concentration of I.A Thiamethoxam	I.A Initial Seed		I.A in leachate samples		I.A in seeds after leaching	
	$\mu g\ L^{-1}$	%	$\mu g\ L^{-1}$	%	$\mu g\ L^{-1}$	%
Control	0.00	0	0.00	0	0.00	0
Trat fito	2214.28	100	1522.62	69	691.66	31
Trat fito+ Florite 1127®	2214.28	100	1675.97	76	538.31	24
Trat fito+ Solid Resin GV5®	2214.28	100	937.10	42	1277.18	58
Trat fito+ Polyseed CF®	2214.28	100	1041.27	47	1173.01	53
Trat fito+ VermDynaseed®	2214.28	100	1028.02	46	1186.26	54

By the soil profile, the leaching process of chemical products depends on some factors, among which is the physico-chemical composition of the soil (MILHOME et al., 2009). The present work was conducted in sand, in order to reduce chemical retention through the soil particles, to facilitate the simulation and quantification of phytosanitary products losses. However, environmental losses occur in soils with different textures. In reports by Castro et al. (2008), using thiamethoxam through the commercial product Actara 250 WG, applied at the beginning of the rainy season in typical Acriférrico Red Latossolo (LVwf) and typical Red-Yellow Distrophic Argissolo (PVAd), 53.8 and 19.4% of the chemical were detected, respectively, and percolated through lysimeters installed at 0.45 m below the soil surface, after rainfall. The ability of thiamethoxam to bind to the mineral particles of clay and organic matter through sorption is greater in clayey soils as compared to more sandy soils. Leaching is prevented to a greater extent by the presence of more organic matter (BROZNIĆ et al., 2012; ROY et al., 2014).

Avelar et al. (2012) observed that maize seeds coated with the PolySeed CF polymer had five times more efficiency in the retention of Furazin 310 TS® insecticide containing 210 g zinc L^{-1}, used for the treatment of seeds. Of the insecticides compared to seeds that did not receive polymers, quantified by the amount of zinc extracted in 100 cm^3 of sand after a 50 mm precipitation; however the other polymer used Color Seed C3, was not efficient in the insecticide retention, because the zinc was leached up to twice as much as the treatment with insecticide alone. The authors (AVELAR et al., 2012) attributed these results to the lack of compatibility and low adhesion of the Color Seed C3 polymer and the insecticide used in the treatment. Similarly in this work, the Florite 1127® polymer (Tables 4 and 5) may have presented incompatibility and lack of adherence to the insecticide thiamethoxam, since it was inefficient in retaining the insecticide with the seeds.

Thiamethoxam foram residues were found in soil sediments, in rice fields of Rio Grande do Sul, in the 0 to 0.10 m depth layer in the amounts of 228.09 to 44.38 $\mu g\ L^{-1}$ collected on the third and 28th days after application (MATTOS et al., 2015), being a high amount of toxic waste present in the environment for an extended period. This amount would protect the seeds and seedlings against the attack of *Oryzophagus oryza* by adhering to the seeds, but the dispersion of the insecticide would be detrimental to many non-target organisms. Thiamethoxam is an insecticide widely used in rice fields in Rio Grande do Sul and wastes are easily found in surface waters and could result to groundwater contamination (MARTINI et al., 2012; TELÓ et al., 2015).

The recommended time for rice sowing in the region of Central Depression of Rio Grande do Sul is in Spring, at the beginning of the rainy season, between October 11 and November 20, for medium-cycle cultivars (STEINMETZ; BRAGA, 2001). In El Niño years, rainfall is more intense from October to December (PAULA et al., 2010), if sowing in the form of the conventional system of the 2015/2016 rice harvest occurred in this period (with high rainfall rates), probably a large part of the chemicals (such as thiamethoxam, applied initially to the seeds), would have been leached to the soil profile. However, the technique of chemical treatment and coating with polymers can be regarded as one of the ways of minimizing insecticide losses, since it is used in the treatment of seeds, contributes to the greater protection of seeds against pest attack soon after sowing and reduces insecticide losses by leaching.

CONCLUSION

Seed treatment with Maxim XL® fungicide (ia: metalaxyl-M 25 g L^{-1} + fludioxonil 10 g L^{-1}), Cruiser 350® FS insecticide (thiamethoxam 350 g L^{-1}) coated with Florite polymers 1127®, Solid Resin GV5®, Polyseed CF® and VermDynaseed®, do not affect the physiological quality of rice seeds.

Solid Resin GV5®, Polyseed CF® and VermDynaseed® polymers are efficient at retaining thiamethoxam together with rice seeds, preventing some of the active ingredients of the insecticide from being leached through the sand columns, shortly after rainfall.

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