MILLET SEEDS MIXED WITH PHOSPHATE FERTILIZERS

Rogério Peres Soratto[1]*; Eduardo do Valle Lima[1]; Munir Mauad[1]; Roberto Lyra Villas Boas[2]; João Nakagawa[1]

[1]*UNESP/FCA - Depto. de Produção Vegetal, Fazenda Experimental Lageado, s/n - C.P. 237 - 18603-970 - Botucatu, SP - Brasil.*
[2]*UNESP/FCA - Depto. de Recursos Naturais.*
**Corresponding author <soratto@fca.unesp.br>*

ABSTRACT: The small size of millet seeds is the main cause for lack of uniformity at sowing, especially because most farmers do not have appropriate seeders. Mixing seeds and phosphate fertilizers would improve seeding, resulting in a better crop stand. To study the effects of such mixture on the physiological quality of seeds, millet seeds were mixed with single superphosphate or triple superphosphate (1 kg of seeds: 2.5 kg of fertilizer), and stored in plastic bags for 0, 6, 12, 24, 48, 72, 96 and 120 hours before sowing, under laboratory conditions. After storage, seeds were separated and their moisture and electrical conductivity were determined. Seeds were then submitted to germination test under laboratory conditions. Seeds mixed with fertilizer and non-mixed seeds, utilized as a control, were sown under greenhouse conditions and the percentage of emergence and seedling emergence speed were determined. Because of acidic residues, the single and triple superphosphates negatively affected the germination and vigor of millet seeds proportionally to the increase in time of contact with the fertilizer.
Key words: *Pennisetum glaucum,* germination, vigor, single superphosphate, triple superphosphate

SEMENTES DE MILHETO MISTURADAS COM FERTILIZANTES FOSFATADOS

RESUMO: O tamanho reduzido das sementes de milheto dificulta sua semeadura uniforme, principalmente para os produtores que não possuem semeadoras apropriadas. Assim, a mistura das sementes com os fertilizantes fosfatados vem sendo utilizada para facilitar a semeadura. Entretanto, o período de contato pode provocar prejuízos na germinação e no vigor. Avaliou-se a qualidade fisiológica das sementes de milheto submetidas a diferentes períodos de contato (0, 6, 12, 24, 48, 72, 96 e 120h) com os fertilizantes superfosfato simples (SFS) e superfosfato triplo (SFT), em um experimento em delineamento inteiramente casualizado em esquema fatorial 8x2 (n=4). Os atributos químicos e físicos dos fertilizantes foram previamente determinados. Foi utilizada a proporção de 1 kg de sementes para 2,5 kg de fertilizante. Após manutenção da mistura em saco plástico no laboratório, as sementes foram separadas dos fertilizantes e submetidas à determinação de umidade, germinação, primeira contagem e condutividade elétrica. Paralelamente, na casa de vegetação, em caixas plásticas contendo terra, determinou-se a emergência e o índice de velocidade de emergência, sem e com a manutenção dos fertilizantes. Porque apresentam resíduos ácidos, tanto SFS como SFT afetaram de maneira semelhante e negativamente a germinação e o vigor das sementes de milheto em mistura, na medida em que se aumentou o período de contato.
Palavras-chave: *Pennisetum glaucum,* germinação, vigor, superfosfato simples, superfosfato triplo

INTRODUCTION

Millet (*Pennisetum glaucum* L. R. Br.) is a tropical grass utilized as cover crop under the no-till system, especially in regions of the Brazilian cerrado. In addition to its dry mass yield, the grain can be utilized to formulate balanced feeds for poultry, swine, caprine and fish (França et al., 1996; Nunes et al., 1997). It is also utilized for grazing, and the phytomass above the ground can be cut and used for silage and hay. Millet main traits are fast and erect growth, with heights ranging from 1.50 to 1.80 m, in a cycle of 130 to 160 days (Salton & Kichel, 1997). Millet is considered a rugged species, indifferent to soil texture and tolerant to low fertility. It also shows medium cold tolerance (Pinto & Crestana, 1998), good tolerance to drought, great dry mass yield potential and its seeds can be easily produced. Even capable of yielding under adverse conditions, millet responds well to mineral fertilization or to more fertile soils with good water availability (Lima, 2001). Therefore, the natural deficiency of Brazilian soils with regard to phosphorus, in addition to the high rate of fixation experienced by this element, makes phosphorous fertilization a necessary practice in many instances (Sader et al., 1991; Cavariani et al., 1994).

Another important aspect of millet cropping concerns the implementation of the crop, the greatest difficulty being mechanical sowing, since the reduced size of seeds, under 2.0 mm, makes it difficult achieving uniform distribution and, consequently, obtaining the ideal population of plants. This characteristic brings additional difficulties to most Brazilian farmers, who do not have access to seeders with precise and proper controls to deliver good, isolated distribution of small seeds and fertilizers.

A possible solution would be resorting to an old practice, frequently utilized for pasture establishment, which consists in previously mixing the seeds with phosphate fertilizers, which work as a vehicle for seeding (Bacchi, 1974; Roston & Kuhn Neto, 1978). However, it is recommended that seeding of homogeneous mixtures of phosphate fertilizers with seeds, to be done without delay, avoiding physiological quality damage (São Paulo, 1973; Moura, 1984). Prolonged contact of fertilizer and seeds can cause germination and vigor losses, depending on the type of the phosphate fertilizer utilized (Cavariani et al., 1994). Several authors have also mentioned that depressive effects that might distress seeds can be attributed to the period of contact with phosphate fertilizers (São Paulo, 1973; Bacchi, 1974; Moura, 1984; Sader et al., 1991; Lima et al., 2000a).

An additional question that needs to be answered concerns the effect phosphate fertilizers have on seeds in the soil, a few days after sowing, since high rates of single superphosphate can reduce seedling population up to 60%, because of injuries to seed embryos, because of fertilizer's placement relative to the seed (Kluthcouski et al., 1999). Such fact can be even more serious when fertilizers are mixed with the seeds before sowing, providing a continuation of the deleterious effects after that operation. The objective of the present work was to evaluate germination and vigor in millet seeds after different contact periods with single superphosphate and triple superphosphate as fertilizers.

MATERIAL AND METHODS

The research was carried out under laboratory and greenhouse conditions. The experimental design was a completely randomized setup, with four replicates. Treatments were arranged in a 8 x 2 factorial scheme, consisting of different contact periods of millet seeds (0, 6, 12, 24, 48, 72, 96 and 120 hours) with granular fertilizers single superphosphate – SSP [$Ca(H_2PO_4)_2CaSO_4$] and triple superphosphate – TSP [$Ca(H_2PO_4)_2$]. Fertilizer's chemical and physical attributes were previously determined (Table 1).

The mixture was in the proportion of 1 kg millet seeds to 2.5 kg fertilizer, based on Lima et al. (2000b); a sample of seeds was previously taken to stand as control. Seeds were homogeneously mixed with the fertilizers, placed in plastic packages and maintained under laboratory conditions, with room temperature ranging from 25 to 28ºC and relative humidity from 45 to 65% (Lima et al., 2000a). After each preset contact period had elapsed, 100 g of the mixture were taken at random and 80 g used to separate seeds from fertilizers by sieving (4; 2; 1.19; 1mm and bottom) and brushing. Only seeds retained in the 1.19mm sieve were utilized, since they represented the largest fraction of the population. The remaining 20 g of the mixture were immediately seeded together with the fertilizers, as a simulation of field conditions.

Seeds which had been separated from the fertilizers were submitted to water content determination, by oven-drying at 105ºC ± 3ºC for 24 hours, and to a germination test under constant temperature at 25ºC, in the absence of light. Fifty seeds were sown per replicate, over a paper towel placed inside a plastic box (gerbox). Evaluations for the first count were done on day 3 and for the final count on day 7, according to Brasil (1992). The electric conductivity test (EC) was also performed over four subsamples of 50 seeds. Subsamples were weighed and placed inside a container with 75 mL distilled water, maintained in an incubator at 25ºC for 24 hours. The exu-

Table 1 - Chemical and physical attributes of granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP) utilized in a mixture with millet seeds, before installation of the experiment.

Fertilizer	Solubility P_2O_5		pH* (H_2O)	EC*	Saline index**	Water content
	H_2O	Neutral Citrate + H_2O				
	------------------ % ------------------			mS cm^{-1}		------ % ------
SSP	15.87	19.9		7.6	8	4.99
TSP	45.05	46.8	3.04	13.9	10	6.15
Fertilizer	Granulometry (mm)				Density	
	4.00	2.83	2.00	0.84	g dm^{-3}	
	-------------------------------- % ------------------------------------					
SSP	2.12	25.42	68.24	4.22	1.25	
TSP	2.24	33.04	59.21	5.51	1.26	

*Determined in a 10% fertilizer solution. **Determined relatively to sodium nitrate taken as index 100.

date reading was performed in a conductivity meter, and the value was expressed as a function of the initial weight of seeds in µS cm^{-1} g^{-1} (AOSA, 1983).

Seeds which had been separated from the fertilizers were sown in a dystrophic clayey Rhodic Hapludox: pH ($CaCl_2$ 0.01 mol L^{-1}) = 4.7; M.O. = 23 g dm^{-3}; P (resin) = 2 mg dm^{-3}; H+Al = 34 $mmol_c$ dm^{-3}; exchangeable K, Ca and Mg = 0.1; 6 and 7 $mmol_c$ dm^{-3}, respectively; SB and CEC = 13 and 48 $mmol_c$ dm^{-3} and V% = 28, in a greenhouse, average temperature 30ºC. Fifty seeds were distributed equidistantly in 2-L square boxes, totaling four replicates per treatment. In addition, 0.5 g of the mixture containing exactly 50 seeds was sown in a furrow, inside 5-L rectangular boxes, 28cm in length. The substrate was moistened at 70% of the field capacity. Daily counts of the number of emerged seedlings were taken, and the percentage of emergence, and emergence speed index (ESI) were determined, according to Maguire (1962). Seedlings were collected ten days after emergence, dried in a forced-ventilation oven at 65º C until constant weight and then weighed to determine dry matter mass (DM) of the aerial part.

Data were submitted to analysis of variance. A comparison of means was performed for factor phosphate fertilizer by Tukey test (P<0.05), while for factor contact period a polynomial regression analysis was done, and regressions with the greatest coefficient of determination (R^2) were selected among the significant by F test. All calculations were performed using SANEST sofware package, according to Zonta & Machado (1991).

RESULTS AND DISCUSSION

No effect of the interaction between phosphate fertilizers and period of contact with seeds was detected (P > 0.05) (Table 2). Therefore, isolated effects of these factors were discussed separately.

The period of contact with the fertilizer influenced water content in the seeds and the mean values were better fitted to a linear function (Figure 1A). There was an increase in water content in seeds with the increase in time they remained mixed with the fertilizers, regardless of the fertilizer utilized. The most significant increase occurred up to 12 hours, and was practically stabilized with time. Water contents presented by SSP and TSP (Table 1) are considered acceptable (CAC, 1986), i.e., around 6%. Neither SSP nor TSP are very hygroscopic (Marzinotto Filho et al., 1988). Once they were in a tightly sealed environment with millet seeds, it is believed they did not have enough moisture available to absorb water. The low EC and low saline index found in the fertilizers (Table 1) further confirm it is not possible for water within the seeds to move towards the fertilizer. Therefore, despite the fact that millet seeds have higher moisture content than fertilizers, the strength seeds need to exercise to extract water is usually quite high (Carvalho & Nakagawa, 2000). It is a known fact that water absorption occurs through the seed coat. Therefore, the homogeneous mixture fertilizer + seeds provided a fast water inflow to the seed (until 12h), and equilibrium was reached from there on.

Phosphate fertilizers did not have any effects on seed germination (P > 0.05), (Table 2). However, this trait was significantly influenced by the period of contact of the fertilizers with the seeds. Figure 1B shows that 6 hours after mixing, it was already possible to observe the negative effect of the contact with fertilizers on seed germination. This variable decreased markedly and progressively with time. These results corroborate those obtained by Lima et al. (2000a), while studying contact periods of Italian millet seeds (*Panicum dichotomiflorum* Mix.) with TSP.

Table 2 - Water content, germination, first count and electric conductivity (EC) of millet seeds as a function of contact period with granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP)[1].

Factor	H_2O Content	Germination	1st Count	EC
Fertilizer	%			µS cm^{-1} g^{-1}
SSP	9.5 a	43.0 a	37.0 a	141.0 a
TSP	9.2 a	44.9 a	36.1 a	131.5 b
	F Value			
Fertilizer (F)	3.0^{ns}	1.5^{ns}	0.4^{ns}	7.1*
Time (T)	12.0**	148.6**	119.7**	55.3**
Linear Regr.	38.5**	1007.3**	795.1**	360.2**
Quadratic Regr.	6.7*	16.7**	20.7**	3.0^{ns}
Interaction FxT	2.1^{ns}	2.0^{ns}	1.5^{ns}	1.6^{ns}
CV(%)	3.8	14.1	17.0	10.4

[1]Means followed by a common letter, within the column, do not differ by Tukey test (P < 0.05). *and **significant F test, P < 0.05 and P < 0.01, respectively; ns – non significant.

Similar effects were also verified in the seed mixture of *Brachiaria brizantha* (Hochst. Ex. A. Rich) Stapf and *Brachiaria decumbens* Stapf with different phosphate fertilizers (Sader et al., 1991; Cavariani et al., 1994). Similarly to what had already been reported by Lima et al. (2000a), it was observed a detrimental effect along the period during which the seeds remained mixed with granular phosphate fertilizers, which are obtained through acid pathways, not only on germination but also with respect to vigor (first count and EC). Phosphate rock processing with the use of sulfuric (SSP) and phosphoric (TSP) acids leaves residues which negatively influence seed germination and vigor when mixed with the fertilizers, and this effect is increased by extended contact.

No effect of fertilizers on seed vigor was observed, when vigor was evaluated by the first count test ($P > 0.05$) (Table 2). However, a progressive decline was verified (Figure 1C) in the percentage of normal seedlings at first count, during the seed contact with fertilizers. Data were best fitted to a quadratic function.

With respect to EC, a quick test related to the early events in the seed deterioration sequence, such as degradation of cell membranes and electrolyte leaching, an inverse relationship with germination and first count was observed, indicating that its determination appropriately characterizes seed vigor (Dias & Marcos Filho, 1996). EC increased with extending contact of seeds with the phosphate fertilizers, which confirms the inverse relationship between this test and germination and first count (Figure 1D). Differences were found between the effects of fertilizers with regard to EC (Table 2), and SSP was responsible for greater damage to millet seeds, probably because its sulfuric acid residue is chemically stronger than the phosphoric acid residue in TSP. However, this differentiated effect was not strong enough to modify germination and first count (Table 2).

Vigor tests conducted in the soil (emergence, ESI and DM) were performed by either maintaining or not the phosphate fertilizers together with the seeds, after the preset contact periods in the mixture. Only with regard to DM in the aerial part of the seedlings, no significant interaction was verified between factors fertilizers x contact period, in treatments where seeds were deposited together with fertilizers (Table 3). Regarding the other variables, the graphical representation of regression equations are partitioned as a function of the period of contact of seeds with SSP and TSP, when seeded in the absence or presence of fertilizers (Figures 2, 3 and 4).

Emergence and ESI were influenced by the period of contact of seeds with the fertilizers and by the interaction between type of fertilizer and period of contact in the mixture (Table 3). There was a rapid and progressive decrease in emergence and ESI of millet seeds, as the period of contact with the phosphate fertilizers in-

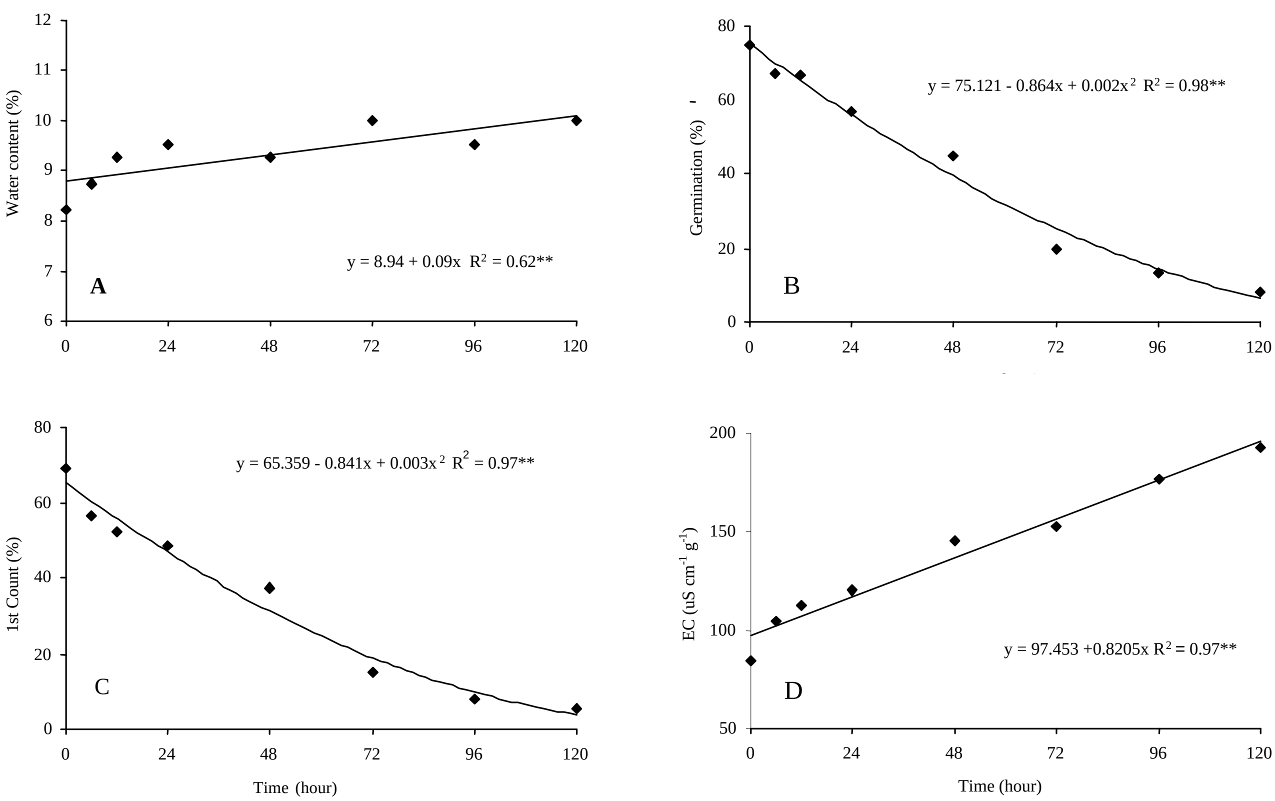

Figure 1 - Water content (A), germination (B), first count (C) and electric conductivity (D) of millet seeds as a function of contact period with granular fertilizers single superphosphate or triple superphosphate.

creased (Figures 2 and 3). Lima et al. (2000a), working with Italian millet, reported a similar behavior of emergence as a function of contact period with TSP. Bacchi (1974), however, verified that Guinea grass seeds (*Panicum maximum* Jacq.) had their emergence reduced as the storage period increased, when mixed with superphosphates, irrespective of being sown with or without the fertilizer. As to the permanence of fertilizers next to seeds in the soil, after the contact periods spent in the mixture, it must be noted that the acid effect of SSP and TSP on

Table 3 - Emergence, emergence speed index (ESI) and dry matter mass (DM) of aerial part of millet seedlings as a function of contact period of seeds with granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP), when seeded in the absence or presence of phosphate fertilizers[1].

Factor	Sowing (seed)			Sowing (seed+fertilizer)		
	Emerg.	ESI	DM	Emerg.	ESI	DM
Fertilizer	----- % -----		g plant^{-1}	----- % -----		g plant^{-1}
SSP	41.9 a	8.2 a	0.0034 a	41.6 a	8.0 a	0.0056 b
TSP	46.2 a	9.2 a	0.0038 a	43.7 a	8.3 a	0.0066 a
	F Value					
Fertilizer (F)	2.9^{ns}	3.6^{ns}	6.6*	1.2^{ns}	0.7^{ns}	8.6**
Time (T)	37.5**	45.2**	15.4**	57.3**	97.8**	13.6**
Linear Regr.	248.6**	284.7**	70.8**	379.7**	651.9**	69.5**
Quadratic Regr.	13.9**	21.5**	1.9^{ns}	1.1^{ns}	2.7**	14.7**
Interaction FxT	3.7**	3.8**	3.9**	2.5*	3.9**	1.9^{ns}
CV(%)	23.0	24.3	16.0	18.8	16.4	22.3

[1]Means followed by a common letter, within the column, do not differ by Tukey test ($P < 0.005$) . * and ** significant F test, $P < 0.05$ and $P < 0.01$, respectively; ns – non significant.

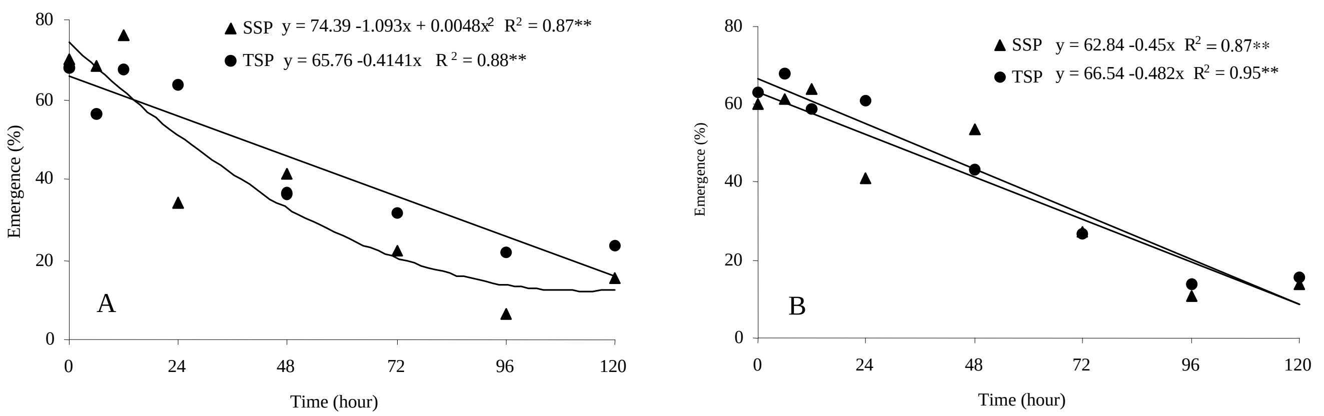

Figure 2 - Emergence of millet seedlings in the soil as a function of contact period of seeds with granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP), when seeded in the absence (A) or presence (B) of phosphate fertilizers.

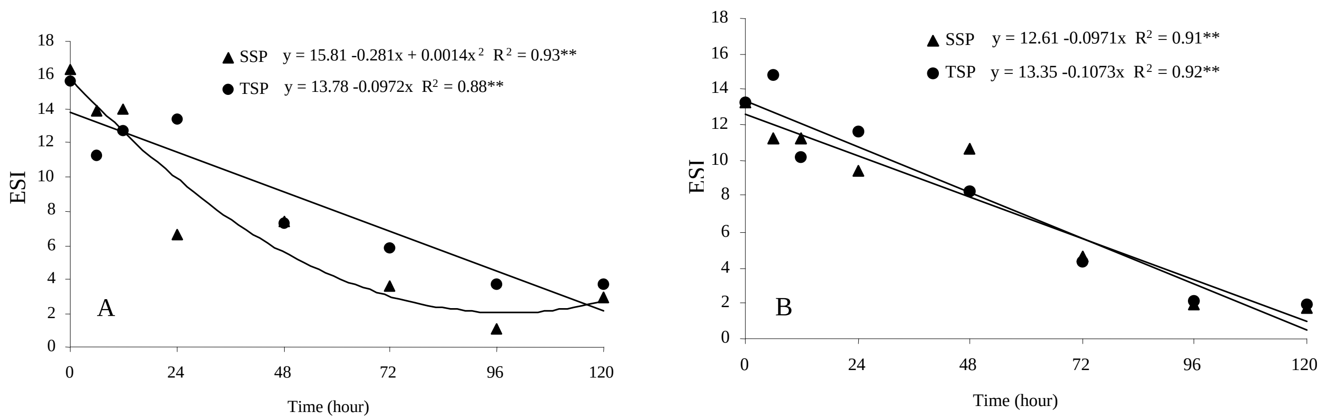

Figure 3 - Emergence speed index of millet seedlings in the soil as a function of contact period of seeds with granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP), when seeded in the absence (A) or presence (B) of phosphate fertilizers.

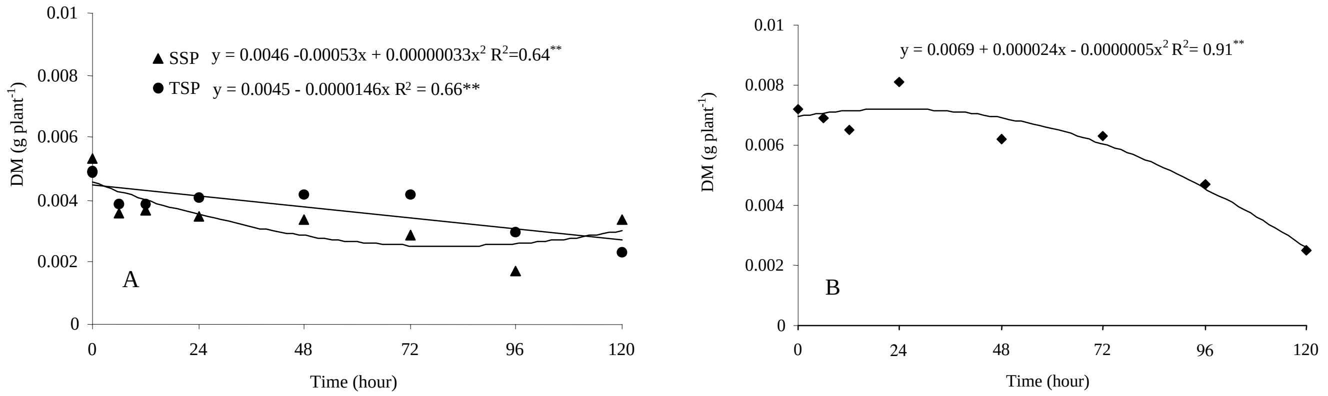

Figure 4 - Dry matter (DM) in the aerial part of millet seedlings cultivated in the soil as a function of contact period of seeds with granular fertilizers single superphosphate (SSP) and triple superphosphate (TSP), when seeded in the absence (A) or presence (B) of phosphate fertilizers.

emergence and ESI was not potentialized (Figures 2 and 3). In the soil, SSP and TSP do not significantly generate acidity. However, the fertilizers are originally acid, and when placed in water, pH measurements will result in values equal to those presented in Table 1.

Determining DM mass in aerial part of seedlings is a test which indicates seed vigor (Carvalho & Nakagawa, 2000). Growing in the absence of phosphate fertilizers, in addition to the fertilizer x contact period interaction, led to an effect of the type of fertilizer utilized in the contact mixture, but it was not detected in the comparison between SSP and TSP means (Table 3). Therefore, a negative effect was observed for both fertilizers on DM mass in the aerial part. For the sowing done in the presence of fertilizers (Figure 4A), TSP produced seedlings with greater DM mass in the aerial part (Table 3), probably because this fertilizer caused a less intense negative effect on vigor (Table 2), and because more phosphorus was available for absorption by seedings (Table 1), enhancing growth, as a result of the important role this element plays in the synthesis of proteins, carbohydrates and lipids. However, the DM mass in the aerial part, regardless of the utilized fertilizer, decreased with extended contact (Figure 4B).

It is possible to recommend millet sowing immediately after mixing the seeds with single superphosphate and triple superphosphate, as long as sowing is done as early after mixing as possible, to avoid substantial losses in physiological quality. The longer the contact period, the greater the damage to the physiological quality of seeds.

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