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Phosphorus Capture by Triticale (X Triticosecale Wittmack) Forage Fertilized with Solarized Cattle or Sheep Manure

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Abstract: In order to study, the effect of solarization of cattle and sheep manure on phosphorus capture by triticale forage, a factorial experiment 2×2×4 was developed with 2 types of cattle and sheep manure, two treatments, non-solarized and solarized and 4 levels of application 0, 80, 120 and 160 ton ha^{-1} with 3 replicates for this purpose, 1×1 m plots were used with a used plot of 0.5×0.5 m sown with triticale. Manure was solarized for a period of 90 days, using manure from dairy cattle fed pastures, alfalfa and concentrate and manure of pasture-fed sheep. For solarization, a 1 mm thick transparent rubber was used to cover manure. Forage samples were taken at the time that the grain was in a milky pasty stage to analyze the content of phosphorus in seed, stem and leaf. The results show a positive effect of manure solarization on phosphorus capture by the different parts of the plant, similarly a higher effect of sheep on cattle manure was observed. In the case of seeds when manure is provided solarized at a rate of 80 kg ha^{-1}, mean values are obtained of extra gain of 4.3 kg ha^{-1} of phosphorus attributable to solarization. For solarized sheep manure at equivalent rates of 120 ton ha^{-1} it was found extra mean values of 6.8 kg ha^{-1} of phosphorus attributable to sheep manure solarization at equivalent rates of 120 kg ha^{-1}. In the case of phosphorus in the stems, bovine manure, solarization negatively affects phosphorus capture by the triticale plant. In the sheep manure, at equivalent rates of 120 ton ha^{-1} of solarized and non-solarized manure, values of 10.6 and 8.9 kg ha^{-1} of phosphorus are obtained, respectively with a difference of 1.7 kg ha^{-1} of captured phosphorus attributable to solarization. In the case of capture of phosphorus by leaves, treatment with solarized sheep manure mean values were obtained from 22.1 kg ha^{-1} of phosphorus, against 14.1 kg ha^{-1} of phosphorus when solarized and non-solarized manure was provided, respectively with a difference of 8 kg ha^{-1} attributable to solarization when solarized manure is provided at rates equivalent to 160 ton ha^{-1}.

Key words: Manure, cattle, sheep, phosphorus, phosphorus capture, triticale, forage

INTRODUCTION

Review of literature: Production systems with high concentrations of animals are highly efficient for the production of animal protein but produce a large volume of manure that is poorly distributed, overloading the soil of nutrients, especially nitrogen and phosphorus, so that the existence and expansion of these forms of production depend on the efficiency of the recycling of these nutrients generated in farms (Kalbasi and Karthikeyan, 2004). The excretion of Phosphorus (P) in feces is related to its consumption. The linear relationships between phosphorus in feces and consumed phosphorus are related according the following equations (Kebreab *et al.*, 2009). In sheep:

$$P_{feces}\,mg\left[d.kg\,live\ weight\right]^{-1} = 9.4 + 0.68\left(P_{ingested}\,mg\left[d.kg\,live\ weight\right]^{-1}\right);\ r^2 = 0.98$$

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For cows in experiment 1:

$$P_{feces}\,mg\left[d.kg\,live\,weight\right]^{-1} = 2.1 + 0.72\left(P_{ingested}\,mg\left[d.kg\,live\,weight\right]^{-1}\right); r^2 = 0.84$$

For cows in experiment 2:

$$P_{feces}\,mg\left[d.kg\,live\,weight\right]^{-1} = -8.3 + 0.68\left(P_{ingested}\,mg\left[d.kg\,live\,weight\right]^{-1}\right); r^2 = 0.71$$

In the case of growing sheep:

$$P_{feces}\ g\ d^{-1} = 0.45(\pm 0.10)\ P_{ingested}\ g\ d^{-1} + 1.25\ (\pm 0.47);\ r^2 = 0.65$$

Although, the form and level of P in the diet influence the concentration of P in manure and can affect P loss from lands to which manure is applied, a diet with an excess of inorganic P to dairy cows increases the potential of P removed by runoff from land where manure is applied even when applied at the same rate (Ebeling *et al.*, 2002).

The livestock manure and compost are applied to the soil to add organic matter and nutrients, improving thus soil physical properties to influence in an important way on water infiltration and erosion control; in addition manure has shown that can suppress some pathogens in the soil (Klonsky and Tourte, 1998).

The application of manure or manure compost results in an increase in the concentration of nutrients and organic matter in soil (Chang *et al.*, 1991; Bahman, 2002). However, when agricultural fields are flooded water that runs off and drains contributing to environmental P, the magnitude of P that is downloaded by water is related to the chemical and physical characteristics of soil, sediments and many environmental variable factors such as soil-water redox potential, depth of water, temperature and turbulence (Sallade and Sims, 1997; Young and Ross, 2001). Although, many soils have a high capacity to absorb P, the prolonged application of poultry manure often results in a saturation of P, particularly near the surface (Kingery *et al.*, 1994; Robinson *et al.*, 1994). In general, the surfaces of P-enriched soils are a source of dissolved P (Sharpley *et al.*, 2004). Research has shown that soils with high concentrations of phosphorus results in changes in vegetation, led to continued loss of native vegetation and the vegetation can act as short-term storage of phosphorus which can be rapidly released during senescence (Bostic and White, 2007).

To reduce the potential environmental risk due to the excessive level of nutrients, the application rate must not exceed the capacity of soil and plant (Adeli *et al.*, 2003). The characterization of the relative capacity of plants to remove P and other nutrients in soils with high P levels becomes very important (Burns *et al.*, 1985). To recycle nutrients applied to land the use of crops able to use these nutrients is required. Durum wheat *Triticum turgidum* var. *durum* and triticale X Triticosecale Wittmack are recognized for having a great efficiency to capture phosphorous because they provide higher yields than other grains when it is grown with low or high levels of phosphorus (Ortiz-Monasterio *et al.*, 2002). Due to this, the cultivation of triticale is used by dairy farmers for two purposes, to produce forage and remove phosphorus by forage harvested. The available phosphorus did not affect the protein of triticale forage; however, more nitrogen is apparently required to maximize production (Brown, 2009).

The average phosphorus removal was higher for winter triticale but varies between years, the average concentration of phosphorus in the winter forage falls from 0.39% in the 1st year to 0.32% in the 2nd year and 0.25% in the 3rd year, this decline is associated with the content reduction of available phosphorus and this decline of removal comes from a decrease in the biomass production and phosphorus concentration in forage, phosphorus applied over time become less soluble due to factors, such as precipitation and incorporation into organic matter (Brown, 2006).

Within the principles of organic agriculture is the use of farm products (Klonsky and Tourte, 1998). The livestock manure and compost are applied to the soil to add organic matter and nutrients and also to improve the physical properties of soil, influencing in an important way on water infiltration and erosion control, manure has also shown that can suppress some pathogens in soil (Klonsky and Tourte, 1998). As an alternative to chemicals use solarization arises as a process in which temperature rises using solar radiation as energy source. Soil solarization combined with organic matter is a sustainable alternative to fumigation or the use of herbicides for weed control and increase production of cantaloupe (Lira-Saldivar *et al.*, 2004).

Solarization is a hydrothermal process of disinfecting of soil to eliminate pests of plants, this is achieved by passive solar heating and solarization occurs by a combination of physical, chemical and biological mechanisms and it is compatible with other disinfection methods to provide integrated pest management (Stapleton, 2000).

Solarization is financially compatible with other tactics of pest management, so it can be quickly integrated to standard systems of production and can be a valid alternative to fumigation (Chellemi *et al.*, 1997). Soil solarization is an effective method to control many insects, diseases and weeds of soil as the number of pathogens can be reduced from 89-100% (Sikora and ACES, 2009; Stapleton *et al*., 1997). Solarization consists of soil disinfection using solar energy, it is a non-chemical treatment that uses solar energy to heat the soil and its efficiency can be improved by the combination of organic products.

Therefore, the objective of this study was to evaluate the effect of solarized sheep and cattle manures and phosphorus capture by triticale X Triticosecale Wittmack forage.

MATERIALS AND METHODS

Study site: This study was carried out in Valle de Durango, Mexico at a latitude and longitude of 23°57' 09.26"N and 104°33'39.5"W with an altitude of 1875 masl, in the Spring of 2008. Manure of dairy cattle from the stable of the Faculty of Veterinary Medicine was solarized, dairy cows fed perennial ryegrass pasture and concentrate with 17% crude protein and sheep of the same faculty fed perennial ryegrass pasture, freshly harvested and was exposed to the sun covered with special rubber to solarize for 90 days and concentrate of the 17% protein after solarization during 3 months solarized manure was applied at levels of 80, 120 and 160 ton ha^{-1} on plots of 1×1 m with a used plot of 0.5×0.5 m after sowing triticale (X Triticosecale Wittmack) equivalent to 60 kg ha^{-1}, prior land preparation with disc plough equipment. The treatments are shown in Table 1 and 2, plots were irrigated with surface water every 10 days so water was not limiting, at day 59 the grains were in a milky pasty stage.

At the end of the growth, forage samples were taken for analysis. Plant samples were dried and ground for determination of total phosphorus content in seed, stem and leaf by vanadate-molybdate method as discussed below.

Sample preparation for chemical analysis: Samples were collected from the experimental plots when the grain was in a milky pasty stage, in paper bags of 45×25 cm for their transportation to the laboratory. In the laboratory part of the samples were carefully separated into their parts, seeds, stems and leaves in fresh then dehydrated in an oven at constant temperature of 45°C until constant weight then ground in a blender to obtain a

Table 1: Simple interrelationships of phosphorus content in different parts of the plant of triticale 59 days after planting

	Treatments			Phosphorus			
Type of manure	Process	Rate (ton ha^{-1})	n	Seed (kg ha^{-1})	Stem (kg ha^{-1})	Leaf (kg ha^{-1})	Total (kg ha^{-1})
Control	-	-	3.0	6.8^{a}	5.1^{b}	7.7^{b}	19.6^{b}
Cattle	-	-	18.0	8.6^{a}	8.7^{ab}	10.5^{ab}	27.8^{ab}
Sheep	-	-	17.0	10.0^{a}	11.0^{a}	14.0^{a}	35.0^{a}
	Nonsolarized	-	18.0	7.7^{b}	9.7^{a}	11.0^{ab}	28.3^{ab}
	Solarized	-	17.0	11.0^{a}	10.0^{a}	13.5^{a}	34.5^{a}
	-	80	12.0	9.5^{a}	10.0^{a}	10.5^{ba}	30.1^{ab}
	-	120	11.0	10.0^{a}	9.2^{ab}	11.0^{ab}	30.2^{ab}
	-	160	12.0	8.4^{a}	10.2^{a}	14.9^{a}	33.6^{a}

Table 2: Double interactions of the phosphorus content in different parts of the triticale plant 59 days after sowing

	Treatments		Seed		Stem		leaves		Total	
Type of manure	Process	Rates (ton ha^{-1})	n	(kg ha^{-1})	n	(kg ha^{-1})	n	(kg ha^{-1})	n	(kg ha^{-1})
Control	None		3	6.8^{b}	3	5.1^{b}	3	7.7^{b}	3	19.6^{b}
Cattle	Nonsolarized		10	7.5^{b}	10	9.1^{ab}	10	9.6^{ab}	10	26.2^{b}
Cattle	Solarized		9	10.6^{ab}	9	8.4^{ab}	8	11.7^{ab}	8	29.9^{ba}
Sheep	Nonsolarized		8	7.9^{ab}	8	10.5^{a}	8	12.6^{ab}	8	31.0^{ba}
Sheep	Solarized		9	11.9^{a}	9	11.6^{a}	9	15.2^{a}	9	38.6^{a}
Cattle		80	7	8.9^{a}	7	8.5^{ab}	7	10.1^{b}	7	27.5^{ab}
Cattle		120	6	9.4^{a}	6	8.9^{ab}	5	9.6^{b}	5	26.6^{ab}
Cattle		160	6	8.5^{a}	6	9.0^{ab}	6	11.8^{b}	6	29.2^{ab}
Sheep		80	5	10.3^{a}	5	12.2^{a}	5	11.1^{b}	5	33.7^{ab}
Sheep		120	6	11.3^{a}	6	9.7^{ab}	6	12.2^{ab}	6	33.3^{ab}
Sheep		160	6	8.4^{a}	6	11.4^{a}	6	18.1^{a}	6	37.9^{a}
	Solarized	80	6	11.0^{ab}	6	9.4^{a}	6	12.0^{ab}	6	32.4^{ab}
	Solarized	120	6	13.1^{ab}	6	9.8^{a}	5	11.1^{ab}	5	33.6^{ab}
	Solarized	160	6	9.5^{ab}	6	10.7^{a}	6	17.1^{a}	6	37.3^{a}
	Nonsolarized	80	6	8.0^{b}	6	10.7^{a}	6	9.0^{b}	6	27.7^{ab}
	Nonsolarized	120	6	7.6^{b}	6	8.8^{a}	6	11.0^{ab}	6	27.4^{ab}
	Nonsolarized	160	6	7.4^{b}	6	9.6^{a}	6	12.8^{ab}	6	29.8^{ab}

[a, b]Means in the same column with same letter are not significantly different

homogeneous basic sample. This homogeneous basic sample was labeled and stored to be use in subsequent chemical analysis.

Determination of phosphorus: Of the samples of soil or forage, previously homogenized, 0.1 g was taken in a beaker of 150 and 10 mL were added of concentrated nitric acid until the reaction of the sample and then 3 mL of perchloric acid was added. The sample was placed on the grid and heated gently to boiling and evaporation of the acid, it was removed from the grid and let it cool once again, 10 mL of concentrated nitric acid was added and heated on the grid until boiling and evaporation of the acid, it was removed from the grid and let it cool, 10 mL of solution of HCI 1:1 was added, it was covered and heated for 5 min after reaching boiling, let it cool and then the sample was taken with demineralized water in a flask and filtered with Whatman paper No. 2 and it was stored in plastic containers for analysis. Of the digested sample, 5 mL was taken and 5 mL of a perchloric acid solution plus ammonium molybdenum and metavanadate was added, it was left settled for 10 min and read in a spectrophotometer C/4 cells CS-200PC series number 22PC07179.

Results were analyzed using a completely randomized design with factorial arrangement for four levels of manure, 0, 80, 120, 160 ton ha^{-1} with two treatments solarized and nonsolarized, two sources of manure, cattle and sheep with three replicates, using the statistical package SAS 9.1., as shown in Table 1.

Experimental design:

$$Y_{ijk} = \mu + A_i + B_J + C_K + A_i{*}B_j + A_i{*}C_K + B_j{*}C_k + A_i{*}B_j{*}C_K + \epsilon_{ijk}$$

Where:

- i = 3
- j = 3
- k = 4
- Y_{ijk} = The observation of the treatment ijk
- μ = The true effect of the general mean
- A_i = The effect of k-th type of manure, control of cattle and sheep
- B_j = The effect of j-th treatment of manures with nothing, solarized and nonsolarized
- C_k = The effect of i-th levels of manure 0, 80, 120 and 160 ton ha^{-1}
- $A_i{*}B_j$ = The ij-th effect of the interaction type of manure per type of treatment to manure
- $B_j{*}C_k$ = The jk-th effect of the interaction type of treatment per rate
- $A_i{*}B_j{*}C_K$ = The effect of the ijk-th effect of the interaction type of manure per type of treatment per rate
- ϵ_{ijk} = The experimental error

RESULTS AND DISCUSSION

Phosphorus capture per hectare in the triticale seed: The yield of phosphorus in the seed ha^{-1} was unaffected by the addition of manure ($p<0.05$) when cattle manure is added phosphorus values are increased to 8.6 kg ha^{-1} of phosphorus against 6.8 kg ha^{-1} of phosphorus to the control and 10.0 kg ha^{-1} for the treatments based on sheep manure, this represents an increase of 1.8 kg ha^{-1} of phosphorus (8.6-6.8) and 3.2 kg ha^{-1} of phosphorus (10-6.8) for cattle and ovine manure, respectively. When manure is solarized values are increased to 11.0 kg ha^{-1} of phosphorus against 7.7 kg ha^{-1} of phosphorus of that nonsolarized so that it represents an increase of 3.3 kg ha^{-1} phosphorus (11.0-7.7) as average gain attributable to solarization and when applied at rates equivalent to 120 ton ha^{-1} values are increased to 10.0 against 6.8 for the control, representing an increase of 3.2 kg ha^{-1} of phosphorus (10.0-6.8) attributable to the rate (Table 1-3).

When cattle manure is solarized mean values are found of 10.6 kg ha^{-1} phosphorus, against 7.5 kg ha^{-1} of phosphorus when it is not solarized representing a gain of 3.1 kg ha^{-1} of phosphorus (10.6-7.5) attributable to solarization when sheep manure is solarized the values reached are 11.9 kg ha^{-1} of phosphorus against 7.9 kg ha^{-1} of phosphorus of nonsolarized manure, so the extra gain of 4 kg ha^{-1} of phosphorus (11.9-7.9 kg ha^{-1} kg phosphorus) is attributable to solarization of sheep manure. When the cattle dung is provided at equivalent

Table 3: Triple interactions of phophorus content in different parts of the triticale plant 59 days after sowing

Manure types	Treatments Process	Rates (ton ha^{-1})	n	Seed	Stem	Leaf	Total
				(kg ha^{-1})			
Control	None	No	3	6.8^{b}	5.1^{b}	7.7^{b}	19.6^{b}
Cattle	Solarized	80	3	11.4^{ab}	8.0^{ab}	12.7^{b}	32.1^{ab}
Cattle	Solarized	120	2	10.1^{ab}	8.4^{ab}	9.6^{b}	28.1^{ab}
Cattle	Solarized	160	3	8.8^{ab}	8.1^{ab}	12.1^{b}	28.9^{ab}
Cattle	Nonsolarized	80	4	7.1^{b}	8.8^{ab}	8.2^{b}	24.1^{b}
Cattle	Nonsolarized	120	3	7.3^{b}	8.7^{ab}	9.6^{b}	25.6^{b}
Cattle	Nonsolarized	160	3	8.2^{ab}	9.9^{ab}	11.5^{b}	29.6^{ab}
Sheep	Solarized	80	3	10.7^{ab}	10.8^{ab}	11.4^{b}	32.8^{ab}
Sheep	Solarized	120	3	14.7^{a}	10.6^{ab}	12.1^{b}	37.3^{ab}
Sheep	Solarized	160	3	10.2^{ab}	13.3^{ab}	22.1^{a}	45.6^{a}
Sheep	Nonsolarized	80	2	9.9^{ab}	14.4^{a}	10.8^{b}	35.0^{ab}
Sheep	Nonsolarized	120	3	7.9^{ab}	8.9^{ab}	12.4^{b}	29.2^{ab}
Control	None	No	3	6.6^{b}	9.4^{ab}	14.1^{ab}	30.1^{ab}

[a, b]Means in the same column with same letter are not significantly different

rates of 120 ton ha^{-1}, the values found were 9.4 kg ha^{-1} of phosphorus against 6.8 kg ha^{-1} of phosphorus for rate zero, so that 2.7 kg ha^{-1} of phosphorus (9.5-6.8) is attributable to the rate. Similarly for sheep manure at an equivalent rate of 120 ton ha^{-1} of phosphorus a mean of 11.3 kg ha^{-1} of phosphorus was obtained against 6.8 kg ha^{-1} of phosphorus of the control so that 4.5 kg ha^{-1} of phosphorus (11.3-6.8) are attributable to the rate. In the solarized manure at equivalent rates of 120 ton ha^{-1}, a mean of 13.1 kg ha^{-1} was obtained against nonsolarized manure at equivalent rate of 120 ton ha^{-1}, against 7.6 kg ha^{-1} of phosphorus, so that the extra of 5.5 kg ha^{-1} of phosphorus (13.1-7.6) is attributable to solarization of cattle manure at this rate of application. When the cattle manure was provided solarized at rates of 80 kg ha^{-1}, mean values of 11.4 kg ha^{-1} of phosphorus against 7.1 kg ha^{-1} of phosphorus are obtained for the application of nonsolarized manure, so that the extra gain of 4.3 kg ha^{-1} of phosphorus (11.4-7.1) are attributable to solarization. For manure solarized at rate equivalent of 120 ton ha^{-1}, it was found values of 14.7 kg ha^{-1} of phosphorus, against 7.9 kg ha^{-1} of phosphorus for the application of nonsolarized manure, so that the extra gain of 6.8 kg ha^{-1} of phosphorus (14.7-7.9) is attributable to solarization of sheep manure at the equivalent rate of 120 kg ha^{-1}.

Phosphorus capture per hectare in triticale stems: The capture of phosphorus by stems was significantly affected by the different treatments, the cattle manure showed mean values of 8.7 kg ha^{-1} of phosphorus while the control showed 5.1 kg ha^{-1} of phosphorus representing a gain of 3.6 kg ha^{-1} of phosphorus (8.7-5.1) attributable to the application of cattle manure and of 11.0 kg ha^{-1} of phosphorus for the chaos of treatments with sheep manure representing an extra of 5.9 kg ha^{-1} of phosphorus (11.0-5.1), attributable to the application of sheep manure.

When manure is solarized mean values of 10.0 kg ha^{-1} of phosphorus are obtained against 9.7 kg ha^{-1} of phosphorus with nonsolarized manure, so that the difference of 0.3 kg ha^{-1} of phosphorus is attributable to the solarization. And when given at an equivalent rate of 160 kg ha^{-1}, values of 10.2 kg ha^{-1} of phosphorus are obtained, against the control of 5.1 kg ha^{-1} of phosphorus, so the difference of 5.1 kg ha^{-1} phosphorus (10.2-5.1) is attributable to the equivalent rate of 160 ton ha^{-1} (Table 1-3).

When cattle manure is provided solarized, it negatively affects phosphorus capture by the triticael plant because when it is provided solarized values of 8.4 kg ha^{-1} of phosphorus are obtained compared with the values of 9.1 kg ha^{-1} of phosphorus for treatments with nonsolarized manure. However in the case of sheep manure, this negative effect does not occur as for treatments with solarized manure values of 11.6 kg ha^{-1} of phosphorus are obtained against 10.5 kg ha^{-1} of phosphorus for treatments with nonsolarized manure. When the solarized sheep manure is provided at equivalent rate of 120 ton ha^{-1}, values of 10.6 kg ha^{-1} of phosphorus are obtained and for this same rate but without solarizing 8.9 kg ha^{-1} of phosphorus, so the difference of 1.7 kg ha^{-1} phosphorus (10.6-8.9) is attributable to solarization (Table 1-3).

Phosphorus capture per hectare in triticale leaves: The different treatments significantly affected ($p>0.05$) the phosphorus capture by triticale leaves when cattle manure is applied values of 10.5 kg ha^{-1} of phosphorus and 14.0 kg ha^{-1} of phosphorus are obtained for the application of sheep manure while in the control values of 7.7 kg ha^{-1} of phosphorus are found representing an increase of 2.8 kg ha^{-1} of phosphorus (10.5-7.7) for cattle manure and of 6.3 kg ha^{-1} of phosphorus (14.0-7.7) for sheep manure. When manure is solarized values of 13.5 kg ha^{-1} of phosphorus and 11.0 kg ha^{-1} of phosphorus are obtained for treatments with nonsolarized manure, from this a difference of 2.5 kg ha^{-1} of phosphorus (13.5-11) is obtained attributable to solarization. When manure is applied at equivalent rates of 160 ton ha^{-1}, values of 14.9 kg ha^{-1} of phosphorus are obtained against the control that is rate zero of 7.7 kg ha^{-1} of phosphorus, so that the difference of 7.2 kg h^{-1} of phosphorus (14.9-7.7) is attributable to the rate. When manure is solarized treatments show mean values of 11.7 kg ha^{-1} of phosphorus against 9.6 kg ha^{-1} of phosphorus of treatments with nonsolarized manure, so that the difference of 2.1 kg ha^{-1} of phosphorus (11.7-9.6) is attributable to solarization in cattle manure. In the case of treatments with solarized sheep manure values of 15.2 kg ha^{-1} of phosphorus and 12.6 kg ha^{-1} of phosphorus are obtained for treatments with nonsolarized manure, so that the difference of 2.6 kg ha^{-1} of phosphorus (15.2-12.6) is attributed to solarization of sheep manure. When solarized manure is provided at rate equivalent to 160 ton ha^{-1}, values of 22.1 kg ha^{-1} of phosphorus are obtained, against 14.1 kg ha^{-1} of phosphorus, so that this difference of 8 kg ha^{-1} of phosphorus (22-14.1) is attributable to solarization (Table 1-3).

Phosphorus capture per hectare in the triticale plant: The application of manure significantly increases ($p<0.05$) the capture of phosphorus by triticale plants (X Triticosecale Wittmack), for cases of application of cattle manure, it increases to levels of 28.8 kg ha^{-1} of phosphorus and in treatments with sheep manure to levels of 35 kg ha^{-1} of phosphorus compared to control treatments with mean values of 19.6 kg ha^{-1} of phosphorus. When manure is solarized, values of 34.5 kg ha^{-1} of phosphorus, against 28.3 kg $ha^{-1}$of phosphorus for nonsolarized manures representing an increase of 6.2 kg ha^{-1} of phosphorus attributable to solarization. When the cattle manure is solarized values of 29.9 kg ha^{-1} of phosphorus against 26.2 kg ha^{-1} of phosphorus are obtained, for those nonsolarized finding a difference of 3.7 kg ha^{-1} of phosphorus (29.9-26-2) in favor of solarized cattle manure. In the case of sheep manure when it is solarized, values of 38.6 kg ha^{-1} phosphorus, against 31.0 kg ha^{-1} of phosphorus are obtained for treatments with nonsolarized sheep manure, so that the difference of 7.6 kg ha^{-1} of phosphorus (38.6-31.0) represents the increase due to solarization. But when cattle manure is applied to equivalent levels of 80 kg ha^{-1} of phosphorus, the capture of phosphorus is increased to levels of 32.1 kg ha^{-1} against the 24.1 kg ha^{-1} of phosphorus, so that this difference of 8 kg ha^{-1} of phosphorus (32.1-24.1) represents the effect of solarization for this level of application.

In the case of sheep manure, when applied at levels equivalent to 160 ton ha^{-1}, mean values of 45.6 kg ha^{-1} of phosphorus against 30.1 kg ha^{-1} of phosphorus are obtained which is a difference of 15.5 kg ha^{-1} phosphorus (45.6-30.1) which is attributable to solarization at this level.

Brown (2009) reported that triticale can remove amounts of phosphorus ranging from 7.85-40.4 kg ha^{-1} of phosphorus. In this study, it was obtained mean values of 32.1 kg ha^{-1} of captured phosphorus in crops where solarized cattle manure was applied at rates of 80 ton ha^{-1} and mean values of 45.6 kg ha^{-1} for crops with applications of solarized sheep manure at rates of 160 ton ha^{-1}.

Therefore, it is concluded that the triticale (X Triticosecale Wittmack) forage crop is a good alternative for the removal of phosphorus derived from livestock exploitations and the best results are obtained if manure is pre-solarized and rate of 80 ton ha^{-1} for the case of cattle and for sheep manure the rate of 160 ton ha^{-1}. From the above, it is concluded that cattle and sheep manure behave differently and that sheep manure is the one that favors a biggest capture of phosphorus ha^{-1} with extra values of 15.5 kg ha^{-1} of phosphorus, for rates of 160 ton ha^{-1} against the 8 kg ha^{-1} of phosphorus extra for rates of 80 ton ha^{-1} of cattle manure.

CONCLUSION

The capture of phosphorus in different parts of the plants was influenced by type of manure, manure treatment and application rate. In the case of triticale seed when cattle manure is provided solarized at rate of 80 kg ha^{-1}, mean values are obtained of extra gain of 4.3 kg ha^{-1} of phosphorus attributable to solarization. For solarized sheep manure at rates equivalent of 120 ton ha^{-1}, extra mean values of 6.8 kg ha^{-1} of phosphorus were found attributable to solarization of sheep manure at the rate equivalent of 120 kg ha^{-1}, so that solarization and rate have positive effect in the capture of phosphorus being sheep manure that favors a better phosphorus capture than cattle manure, in the case of triticale seed. In the case of phosphorus in the stem, the cattle manure, solarization negatively affects the capture of phosphorus by the triticael plant, mean values of 8.4 and 9.1 kg ha^{-1} of phosphorus were observed for treatments with solarized and nonsolarized cattle manure, respectively. However in the case of sheep manure, the negative effect does not occur when the solarized sheep manure is provided at rates equivalent of 120 ton ha^{-1} of solarized and nonsolarized manure, values of 10.6 and 8.9 kg of phosphorus were obtained, respectively, so that the difference of 1.7 kg ha^{-1} of captured phosphorus is attributable to solarization.

In the case of the capture of phosphorus by leaves, the treatments with solarized sheep manure were able to show mean values of 22.1 kg ha^{-1} of phosphorus, against 14.1 kg ha^{-1} of phosphorus when solarized and nonsolarized manure was provided, respectively with a difference of 8 kg ha^{-1} attributable to solarization when solarized manure is provided at rates equivalent to 160 ton ha^{-1}.

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