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Effect of Vermiculite as an Ameliorant for Paper Mill Effluent Irrigated Soil and on the Productivity of Sunflower

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Abstract: The treatment which received vermiculite at the rate of 5 t ha^{-1} +50% Gypsum (T_5) registered the highest yield of sunflower grain and stalk which was nearly 1.68 and 1.41 folds increase, respectively over the control. The grain and stalk yield of sunflower from the treatment receiving vermiculite alone at the rate of 10 t ha^{-1} (T_4) registered just 1.08 and 1.03% increase over the control. The increase in yield by the application of vermiculite +50% GR might be due to mitigation of the ill effects of Na in this treatment combination by the replacement of Na ion from the soil exchange complex along with the application of vermiculite which could have enhanced the CEC and physical environment of the soil resulting in possible increase in the productivity of the crop. The combined use of vermiculite along with pressmud/gypsum as amendments enhanced the nutrient status apart from providing with better physical and biological environment resulting in significant impact on various plant productivity parameters.

Key words: Vermiculite, sunflower yield, degraded soils, treated paper and pulp mill effluent irrigation

INTRODUCTION

Vermiculite is the geological name given to a group of hydrated laminar minerals that are magnesium-aluminum -iron silicates with a suggested formula of $(Mg, Fe^{+2}, Al)_3$ $(Al, Si)_4 O_{10} (OH)_2 . 4H_2O$ (Fleisher and Mandarino, 1991). Vermiculite is the member of the phyllosilicate mineral group and is micaceous in nature. Flakes of raw vermiculite concentrate are mica-like in appearance and contain water molecules within their internal surface. The word vermiculite is derived from the Latin word meaning to breed worms, alluding to the worm-like shape resulting from its expansion on heating. Vermiculite can absorb such liquids as fertilizers, herbicides and insecticides which can then be transported as free-flowing solids (Harben and Kuzvcort, 1996). Vermiculite, which is available in plenty in mines is very light in weight (90-160 kg m^{-3}), has high water holding capacity (150%) and high cation exchange capacity of 120-130 m.eq/100 g (Jasper, 1981). This precious low cost natural resource with its above favourable qualities could be exploited for treating the wastewater and for remediating soils.

The pulp and paper mill, industry ranks high both in terms of water usage and pollution loads. In India, at present, there are about 350 paper mills in operation with an installed capacity of 3.04 x 10^6 tonnes of paper per annum. It is estimated that 205-315 m^3 of water is required per ton of paper made and practically the entire quantity reappears as effluents. The coloring materials present in the wastewater is organic in nature comprising of wood extractives, tannins, resins, synthetic dyes, lignin and its degradation products formed by the action of chlorine or lignin (Rao and Dutta, 1987). Discharge of coloured pulping effluents to the receiving waters inhibits photosynthetic activity of aquatic biota (Walden and Howard, 1981).

In Tamil Nadu, 24 lakh ha (23.97% of total geographical area) of agricultural lands are highly permeable in nature. In this type of soils, water holding and nutrient retention capacities are low. Similarly, the soils (covering an area of 7.54 lakh ha) are facing the problem of sodicity, aeration and drainage which limit the crop productivity. These soil physical constraints could be improved by the application of vermiculite as an amendment (Jasper, 1981). Hence the present investigation was contemplated to evaluate the effect of vermiculite application along with gypsum and press mud with graded doses of NPK fertilizers in degraded soil on sunflower crop.

MATERIALS AND METHODS

A Field experiment was conducted at Pappampalayam, Erode, Namakkal District, Tamil Nadu.

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Table 1: Description of the treatments

Treatments	Treatment detail
T_1	Control
T_2	Gypsum (GR)
T_3	Vermiculite at the rate of 5 t ha^{-1}
T_4	Vermiculite at the rate of 10 t ha^{-1}
T_5	Vermiculite at the rate of 5 t ha^{-1} + Gypsum (50% GR)
T_6	Vermiculite at the rate of 10 t ha^{-1} + Gypsum (50% GR)
T_7	Vermiculite at the rate of 5 t ha^{-1} + Pressmud at the rate of 12.5 t^{-1} ha
T_8	Vermiculite at the rate of 10 t ha^{-1} + Pressmud at the rate of 12.5 t ha^{-1}

Table 2: Vermiculite and amendments on productive parameters of sunflower under treated paper mill effluent irrigation

Treatments	Single head weight (g)	Head diameter (cm)	1000 grain weight (g)	Grain yield (kg ha^{-1})
T_1	154.00	9.35	40.00	1152.00
T_2	168.00	10.60	41.80	1416.00
T_3	198.00	11.70	44.40	1333.00
T_4	216.00	12.30	45.40	1248.00
T_5	306.00	15.60	58.30	1934.00
T_6	284.00	13.40	53.30	1796.00
T_7	272.00	14.40	52.30	1841.00
T_8	294.00	13.90	51.60	1743.00
Mean	236.00	12.70	48.40	1558.00
SEd	0.864	0.125	0.376	1.56
CD (0.05)	1.854	0.269	0.807	3.34

Calculated amounts of the amendments as per the treatments including the vermiculite (Raw vermiculite grade 2) were uniformly spread in the plots and ridges and furrows were formed. Sunflower seeds (CO_4) were sown on 02.03.2004 adopting a spacing of 60×45 cm. Top dressing of NPK was carried out and need based irrigation scheduling has been done. The experiment was laid out in randomized block design with three replications (Table 1).

The pH of the experimental soil was 8.18, whereas the EC was 0.41 dS m^{-1}. The soil available nutrients were 186, 11.7 and 299 kg ha^{-1} for nitrogen, phosphorus and potassium, respectively. The organic carbon content was 0.49% in the experimental soil. The Exchangeable Sodium percent (ESP) of soil was 15.1. Yield attributes such as single head weight (g), head diameter (cm), 1000 grain weight: 1000 grain of each representative samples were recorded for each treatment and expressed in gram. Sunflower seeds yields were recorded in each treatment (Table 2) and statistically analyzed (Panse and Sukhatme, 1978).

RESULTS

Yield characters: The weight of single head ranged from 154 (T_1) to 306 g (T_5), the later was significantly superior from the rest of the treatments. It was followed by T_8 which registered 294 (Table 2).

Among the treatments, the head diameter ranged from 9.35 (T_1) to 15.6 cm (T_5) which was significantly superior from the rest of the treatments. It was followed by T_7 which registered 14.4 cm (Table 2).

The 1000 grain weight ranged from 40.0 (T_1) to 58.3 (g) (T_5). The highest value in T_5 was followed by T_6 (53.3 g) (Table 2).

The grain yield among the treatments ranged from 1152 to 1934 kg ha^{-1}. The treatment T_5 which received 5 t ha^{-1} of vermiculite and 50% Gypsum (T_5) was significantly superior from the rest of the treatments and recorded the highest grain yield of 1934 kg ha^{-1}. The treatment T_5 was followed by T_7 (1841 kg ha^{-1}). The lowest grain yield was recorded in T_1 (control) (1152 kg ha^{-1}) which was followed by the T_4 (vermiculite at the rate of 10 t ha^{-1}) and T_3 (vermiculite at the rate of 5 t ha^{-1}) which recorded grain yields of 1248 and 1333 kg ha^{-1}, respectively (Table 2).

Soil available nutrients: It was observed that as the stages progressed the available nitrogen content decreased. The lowest available nitrogen content was at harvest stage (179 kg ha^{-1}) and all different stages were significantly different among themselves.

The highest available nitrogen of 207 kg ha^{-1} was observed in treatment T_7 which received (vermiculite at the rate of 10 t ha^{-1} + pressmud 12.5 t ha^{-1}) followed by T_7 (205 kg ha^{-1}) which were significantly different among themselves and from the rest. The lowest available nitrogen of 167 kg ha^{-1} was observed in T_1 (control).

Among the interactions it was observed that T_8 and T_9 of vegetative stage with available nitrogen contents 210 and 209 kg ha^{-1}, respectively were the highest and were on par with each other while being significantly different from the rest. The lowest available nitrogen of 164 kg ha^{-1} was observed in T_1 (control) under flowering stage (Table 3).

The available phosphorus content of vegetative stage 19.8 kg ha^{-1} was the highest and it significantly differed from the flowering stage and harvest stage which recorded 18.4 and 16.8 kg ha^{-1}, respectively. Among the significantly different from the rest of the treatments. The lowest was observed in T_1 (control) with 16.1 kg ha^{-1}

Table 3: Vermiculite and amendments on available nutrient status of soils after harvest under sunflower crop grown with treated paper mill effluent irrigation

Treatments	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1	158.00	14.50	295.00
T_2	164.00	15.50	305.00
T_3	174.00	14.60	305.00
T_4	171.00	15.50	308.00
T_5	179.00	16.90	314.00
T_6	183.00	17.70	314.00
T_7	202.00	19.70	331.00
T_8	204.00	20.20	333.00
Mean	179.00	16.80	313.00
SEd	0.685	0.256	1.161
CD (0.05)	1.380	0.514	2.337

which was on par with T_3 which was 16.2 kg ha^{-1} which was on par with T_3 which was 16.2 kg ha^{-1}. Among the interactions it was observed that the treatment T_8 (25.5 kg ha^{-1}) in vegetative stage recorded the highest and it was significantly different from the rest. The lowest available phosphorus of 14.5 kg ha^{-1} (T_1) which was on par with T_3 (14.6 kg ha^{-1}) in harvest stage was observed.

It was observed that as the stages advanced available potassium content decreased. It was 324 kg ha^{-1} in vegetative stage and 313 kg ha^{-1} in harvest stage. Among the treatments it was observed that T_8 (338 kg ha^{-1}) and T_7 (336 kg ha^{-1}), respectively were the highest and were on par with each other and together they were significantly different from the rest of the treatments. The lowest available potassium content of 302 kg ha^{-1} was observed in T_1 (control) and it was significantly different from the rest of the treatments. The interaction between the stages and treatments was non-significant (Table 3).

DISCUSSION

Grain yield: The treatment which received vermiculite at the rate of 5 t ha^{-1} +50% Gypsum (T_5) registered the highest yield of sunflower grain and stalk which was nearly 1.68 and 1.41 folds increase, respectively over the control. The increase in yield by the application of vermiculite +50% GR might be due to mitigation of the ill effects of Na in this treatment combination by the replacement of Na ion from the soil exchange complex along with the application of vermiculite which could have enhanced the CEC and physical environment of the soil resulting in possible increase in the productivity of the crop as stated by Page *et al.* (1979).

The grain and stalk yield of sunflower from the treatment receiving vermiculite alone at the rate of 10 t ha^{-1} (T_4) registered just 1.08 and 1.03% increase over the control. This could be due to the application of higher dose of vermiculite alone where it exhibited a higher soil pH of 8.51 and EC (0.73 dS m^{-1}). Moreover, the nutrients could have been strongly adsorbed in the adsorption sites making them unavailable for plant nutrition and subsequent productivity enhancement.

Soil available nutrients

Soil available nitrogen: The treatment T_8 (vermiculite at the rate of 10 t ha^{-1} + pressmud at the rate of 12.5 t ha^{-1}) under treated effluent irrigation followed by the combined application of vermiculite at the rate of 5 t ha^{-1} + pressmud at the rate of 12.5 t ha^{-1} (T_7) recorded significantly higher soil available nitrogen. The treatment T_8 increased the available N content in soil by nearly 1.24% over the control. The status of high available nitrogen in pressmud applied plots is in corroboration with Srikanth *et al.* (1992) who stated that pressmud was beneficial in improving nutrient status along with soil physical conditions. The lowest available N was under the treatment receiving 100% GR alone (T_2).

In general, the available nitrogen content decreased at later stages of crop growth under effluent irrigation. The reduction was gradual indicating that a part of nutrient had been utilized by crop for its growth. This is in line with the findings of Mary Celin Sardana (1995) and Hameed Sulaiman and Udayasoorian (1999).

Soil available phosphorus: The treatments T_8 and T_7 which recorded in maximum soil available P may be due to pressmud which is a rich source of nutrients. Kale (1981) reported that pressmud treatment at the rate of 12.5 t ha^{-1} increased the available P in the soil. A gradual reduction in available P in effluent irrigated experimental field soil indicated the crop removal. This was in accordance with the findings of Palaniswami (1990) and Hameed Sulaiman (1997) who reported that there was a gradual reduction in available P in effluent irrigated, solid wastes added soil indicating crop removal.

Soil available potassium: Vermiculite and amendments along with effluent irrigation recorded higher soil available K. The available K was maximum in T_8 and T_7, the percentage increase over the control being 1.29 and 1.35 percentages, respectively. This could be due to mineralization of organic matter in soils by which the availability of K would increase as stated by Igbounamba (1972). It was followed by vermiculite at the rate of 10 t ha^{-1} +50% GR application. Favourable enhancement of available K content of soil due to pressmud + vermiculite application.

The soil available K decreased gradually as the crop growth stage increased. Hameed Sulaiman (1997) reported similar decreasing trend of soil available K with advancement of crop growth in effluent irrigated soils. In general, the results indicated that pressmud improved the soil fertility.

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