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Impact of enriched phosphatic sludge application on growth, yield and uptake of finger millet under field conditions

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Abstract

The field experiment was conducted in finger millet crop during *kharif* 2016 to evaluate the effect of application of enriched phosphatic sludge application on growth and yield parameters of the crop at V.C farm, Mandya which falls in the southern dry zone (zone 6) of Karnataka. It lies between 76°82'01" to 76°82'08" E longitude and 12°57'03" to 12°57'05" N latitude with an average elevation of 699-715 m above MSL. Enriched phosphatic sludge was analysed for various physico- chemical parameters before application to the crop. The sludge was rich in phosphorus (6.88%) and organic carbon (11.50%) content as it was enriched with press mud and sea weed extract at the site of production and storage. Growth parameters like plant height and number of tillers per hill at 30, 60, 90 DAT and at harvest were recorded maximum in treatment with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with treatments receiving RDF + FYM, RDF + EPS @ 500 kg ha⁻¹ and RDF + EPS @ 1000 kg ha⁻¹. Yield attributes like ear head length (cm), number of productive tillers hill⁻¹, number of fingers earhead⁻¹, Test weight (g), Ear head weight hill⁻¹, Grain yield and Straw yield (q ha⁻¹) were recorded maximum in treatment with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with treatments receiving RDF + FYM and RDF + EPS @ 1000 kg ha⁻¹. Uptake of nutrients were recorded maximum in treatment with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with treatments receiving RDF + FYM and RDF + EPS @ 1000 kg ha⁻¹.

Keywords: Enriched phosphatic sludge, finger millet, growth and yield parameters

Introduction

Finger millet (*Eleusine coracana* (L.) is an important small millet crop widely cultivated in semi-arid and tropical regions due to its adaptability to poor soils and drought tolerance. It serves as a staple food for most of the people and is valued for its high nutritional content, particularly calcium, dietary fibre, and essential amino acids. Despite its resilience, the productivity of finger millet remains low in many regions, primarily due to soil nutrient deficiencies, especially phosphorus (P). Phosphorus is a critical macronutrient required for root development, energy transfer, tillering and grain formation. However, in many tropical soils, phosphorus availability is limited because of fixation and low native P content. Continuous cultivation without adequate nutrient replenishment further exacerbates soil fertility decline, resulting in poor crop growth and reduced yields. Therefore, sustainable nutrient management strategies are essential to enhance productivity while maintaining soil health. The nutrient supplying capacity of soil declines steadily under continuous and intensive cropping systems. The use of optimum levels of N, P and K has failed to maintain yield levels, probably due to increasing secondary and micronutrient deficiencies and also unfavourable alterations in the physical and chemical properties of soil. In this context, the byproducts and wastes of different industries such as sludge which are rich in macro, secondary and micro nutrients and low in heavy metals are the most viable choice as the use of such materials in crop production solves their problem coincidentally. Studies showed that the nutrient content of sludge sustains soil fertility and organic constituents improve soil properties (Singh and Agrawal 2010, Meena *et al.* 2013) ^[10, 7]. Sludge generated from the ortho-phosphoric acid manufacturing plant, Karwar, Karnataka, was enriched with press mud, sea weed extract and plant growth hormones to

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improve its physical and chemical properties. Enriched phosphatic sludge is alkaline in reaction with low soluble salts and high organic matter and phosphorus content with moderate N, K and micronutrient content. Hence, it seems to be good for utilization of this enriched phosphatic sludge along with chemical fertilizers for crop production.

Materials and Methods

The field experiment was conducted during the Kharif season of 2016 at the Zonal Agricultural Research Station, V.C. Farm, to evaluate the effect of enriched phosphatic sludge on the growth and yield of finger millet (*Eleusine coracana* (L.)). The experiment was laid out in a Randomized Complete Block Design (RCBD) with twelve treatments and three replications. The finger millet variety KMR-340 was sown at a spacing of 30 cm × 10 cm. All recommended agronomic practices were followed uniformly to ensure optimal crop growth and to maintain experimental precision. The experiment comprised twelve treatments with different levels of enriched phosphatic sludge (EPS) in combination with recommended doses of fertilizers. Physico chemical properties of the sludge were given in the Table 1.

Treatment Details

The treatments were as follows: T₁ - Absolute control; T₂ - Recommended dose of fertilizers (RDF) + Farmyard manure (FYM); T₃ - RDF + EPS @ 125 kg ha⁻¹; T₄ - RDF + EPS @ 250 kg ha⁻¹; T₅ - RDF + EPS @ 500 kg ha⁻¹; T₆ - RDF + EPS @ 750 kg ha⁻¹; T₇ - RDF + EPS @ 1000 kg ha⁻¹; T₈ - Balanced RDF + EPS @ 125 kg ha⁻¹; T₉ - Balanced RDF + EPS @ 250 kg ha⁻¹; T₁₀ - Balanced RDF + EPS @ 500 kg ha⁻¹; T₁₁ - Balanced RDF + EPS @ 750 kg ha⁻¹; and T₁₂ - Balanced RDF + EPS @ 1000 kg ha⁻¹. These treatments were evaluated to assess the effect of graded levels of EPS in combination with fertilizer application on the growth and yield of finger millet.

Characteristics of enriched phosphatic sludge

The sludge was moderately alkaline in reaction (pH 8.06) with medium EC (0.97 dS m⁻¹). The alkaline reaction of the EPS may be due to its mixing with press mud which was generally alkaline in reaction. The EPS had high quantity of phosphorus (6.88%) and organic matter (11.50%) total N (1.51%), K (1.20%), Ca (1.50%), Mg (1.10%) and S (1.50%) content were also in appreciable amounts in the EPS. Similarly, the total Fe, Mn, Zn and Cu contents were 4800, 1200 and 2100 and 67 mg kg⁻¹, respectively. The higher nutrients content in the EPS might be due to its enrichment with pressmud and sea weed extract. Similar results with high content of organic matter (OM), nitrogen (N), phosphorus (P), potassium (K) and other plant nutrients in sludge was reported by Herzel *et al.* 2015 [2]; Rigby *et al.* 2015. Sludge contains heavy metals viz., Cr, Pb and Ni to an extent of 12, 28 and 16 mg kg⁻¹ respectively. However, Cd was not detected in the EPS. All the heavy metals recorded in the EPS were below the permissible limits as per the Indian standards.

Results and Discussion

Growth parameters

Field experiment was conducted at V.C Farm, Mandya in finger millet crop to study the influence of enriched phosphatic sludge (EPS) on the growth and yield parameters of finger millet. Maximum plant height (45.23 cm) was recorded with the application of RDF + EPS @ 750 kg ha⁻¹ at 30 DAT and was found on par with the application of RDF + EPS @ 1000 kg ha⁻¹

and RDF + FYM and the least was recorded in control. At 60 DAT, there was significant increase in plant height (66.80 cm) with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with RDF + FYM (T₂: 64.56 cm) and RDF + EPS @ 500 kg ha⁻¹ (T₅: 62.76 cm). At 90 DAT and at harvest, higher plant height (76.80 and 81.38 cm) was recorded with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with treatments T₂ (75.48 and 76.51 cm) and T₇ (73.81 and 77.33 cm). Significantly, higher number of tillers hill⁻¹ (4.7, 6.03, 6.20 and 6.24 tillers hill⁻¹ at 30, 60, 90 DAT and at harvest respectively) was recorded with the application of RDF + EPS @ 750 kg ha⁻¹ and was found on par with treatments receiving RDF + FYM, RDF + EPS @ 500 kg ha⁻¹ and RDF + EPS @ 1000 kg ha⁻¹ (Table 2). The significant improvement in plant height and number of tillers per hill observed with the application of RDF + EPS @ 750 kg ha⁻¹ may be attributed to enhanced phosphorus availability and improved soil physico-chemical properties. Phosphorus plays a vital role in cell division, root proliferation, and energy transfer processes, which directly influence vegetative growth and tiller production in finger millet (*Eleusine coracana* (L.)). The addition of enriched phosphatic sludge (EPS) along with RDF might have ensured a sustained release of nutrients, thereby supporting crop growth at critical stages. The increased plant height recorded at 60, 90 DAT and at harvest under RDF + EPS @ 750 kg ha⁻¹ indicates better nutrient uptake and efficient utilization. The organic matter present in EPS could have improved soil structure, moisture retention, and microbial activity, which in turn enhanced nutrient solubilization and availability. Similar studies conducted by Kumar and Sharma (2022) [3] reported that phosphorus applications increase nutrient uptake and photosynthetic activity.

Yield parameters

The yield attributes of finger millet, viz., ear head length (cm), number of productive tillers hill⁻¹, number of fingers ear head⁻¹, test weight (g), and ear head weight hill⁻¹ (g), were significantly influenced by graded levels of EPS application (Table 3). Among the different treatments, application of RDF + EPS @ 750 kg ha⁻¹ recorded the highest ear head length (7.15 cm), which was significantly superior to all other treatments. The lowest ear head length (5.10 cm) was observed in the control. Among the treatments receiving balanced RDF with different levels of EPS, higher ear head length (5.83 cm) was recorded with balanced RDF + EPS @ 750 kg ha⁻¹, followed by treatment T₁₂ (balanced RDF + EPS @ 1000 kg ha⁻¹). The number of productive tillers hill⁻¹ differed significantly with varying levels of EPS application over control. The highest number of productive tillers hill⁻¹ (6.05) was recorded with RDF + EPS @ 750 kg ha⁻¹, followed by T₇ (5.42) and T₂ (5.26). Similarly, other yield parameters such as number of fingers ear head⁻¹ (7.57), ear head weight hill⁻¹ (8.93 g), test weight (4.49 g), grain yield (38.74 q ha⁻¹), and straw yield (43.0 q ha⁻¹) were also recorded maximum under RDF + EPS @ 750 kg ha. Similar results were reported by Lavado 2006 [5]; Singh and Agrawal 2007 [9], 2010; Grobelak *et al.* 2017 [1].

Nutrient uptake

Among the different treatments, significantly higher total N (119.83 kg ha⁻¹), P (20.28 kg ha⁻¹) and K (65.91 kg ha⁻¹) uptake by finger millet (grain + straw) was noticed in the treatment T₆, which received RDF + EPS @ 750 kg ha⁻¹ and was followed by treatment which received RDF + FYM. However, lower uptake of total N (43.39 kg ha⁻¹), P (6.96 kg ha⁻¹) and K (23.04 kg ha⁻¹)

was noticed in control. Among the treatments which received balanced RDF, total N (92.99 kg ha⁻¹), uptake was higher in the treatment T₁₂ which received balanced RDF + EPS @ 1000 kg ha⁻¹ and total P (15.77 kg ha⁻¹) and K (51.90 kg ha⁻¹) uptake was higher in the treatment T₁₁ which received balanced RDF + EPS @ 750 kg ha⁻¹. Higher N, P and K uptake was recorded with the application of RDF + EPS @ 750 kg ha⁻¹. Uptakes of N, P and K by straw and grain of finger millet was increased with the increasing levels of sludge application. In addition, apart from the enhanced nutrient supply, the positive influence of the sludge application on the growth of plants and N, P and K uptake could be due to the improving soil properties (Meena *et al.* 2013, Khanmohammadi *et al.* 2017) [7, 4].

With respect to total uptake of iron, manganese, copper and zinc by finger millet (grain + straw), the results showed that significantly higher uptake of iron (331.17 g ha⁻¹), manganese (115.31 g ha⁻¹), copper (32.85 g ha⁻¹) and zinc (185.69 g ha⁻¹) was observed in the treatment T₆ received RDF + EPS @ 750 kg ha⁻¹ followed by treatment T₇ received RDF + EPS @ 1000 kg ha⁻¹ and T₂ received RDF + FYM. Lower uptake of iron (112.71 g ha⁻¹), manganese (46.71 g ha⁻¹), copper (9.83 g ha⁻¹) and zinc (63.06 g ha⁻¹) was noticed in control. Reports showed that DTPA-extractable micronutrients contents in soil were increased under sludge amended soil, which could be a reason for enhancing the uptake of these elements by maize crop (Meena *et*

al. 2008, Zoubi *et al.* 2008, Latore *et al.* 2014, Yang *et al.* 2018) [8, 11, 6, 12].

Table 1: Characterization of enriched phosphatic sludge

Parameter	Value
MWHC (%)	38.10
Bulk density (Mg m ⁻³)	1.06
pH (1:10)	8.06
EC (1:100) dS m ⁻¹	0.97
OC (g kg ⁻¹)	11.50
N (%)	1.51
P (%)	6.88
K (%)	1.20
Ca (%)	1.50
Mg (%)	1.10
S (%)	1.50
Fe (mg kg ⁻¹)	4800
Mn (mg kg ⁻¹)	1200
Cu (mg kg ⁻¹)	67
Zn (mg kg ⁻¹)	2100
Pb (mg kg ⁻¹)	28
Ni (mg kg ⁻¹)	16
Cr (mg kg ⁻¹)	12
Cd (mg kg ⁻¹)	ND

ND- Not detected

Table 2: Effect of enriched phosphatic sludge application on plant height and number of tillers plant⁻¹ in finger millet during *kharif* 2016

Treatment	Plant height (cm)				Number of tillers plant ⁻¹			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T ₁ - Absolute Control	28.61	42.16	52.44	60.38	3.01	4.03	4.20	4.23
T ₂ - RDF+FYM	42.26	64.56	75.48	76.51	4.33	5.63	5.83	5.71
T ₃ - RDF+ EPS @ 125 kg ha ⁻¹	41.79	58.33	64.36	67.81	3.50	4.70	4.87	4.92
T ₄ -RDF + EPS @ 250 kg ha ⁻¹	42.07	57.80	64.49	67.97	3.22	4.97	5.07	5.11
T ₅ - RDF + EPS @ 500 kg ha ⁻¹	40.03	62.76	70.27	74.11	4.27	5.43	5.80	5.63
T ₆ - RDF + EPS @ 750 kg ha ⁻¹	45.23	66.80	76.80	81.38	4.70	6.03	6.20	6.24
T ₇ - RDF + EPS @ 1000 kg ha ⁻¹	42.23	61.78	73.81	77.33	4.13	5.97	6.00	6.00
T ₈ - Balanced RDF + EPS @ 125 kg ha ⁻¹	39.93	53.40	63.41	66.96	3.27	4.49	4.67	4.72
T ₉ - Balanced RDF + EPS @ 250 kg ha ⁻¹	37.39	54.77	63.26	65.67	3.18	4.53	4.53	4.57
T ₁₀ - Balanced RDF + EPS @ 500 kg ha ⁻¹	37.60	54.64	62.53	66.76	3.24	4.67	4.57	4.60
T ₁₁ - Balanced RDF + EPS @ 750 kg ha ⁻¹	37.62	52.38	62.44	66.02	3.20	4.40	4.40	4.46
T ₁₂ - Balanced RDF + EPS @ 1000 kg ha ⁻¹	36.42	51.51	62.84	66.53	3.06	4.37	4.43	4.44
S.Em. ±	1.36	1.69	1.76	1.96	0.17	0.24	0.21	0.25
CD @ 5%	4.00	4.95	5.17	5.75	0.51	0.70	0.62	0.73

Table 3: Effect of enriched phosphatic sludge application on yield attributes and yield in finger millet during *kharif* 2016

Treatment	Yield attributes							
	No. of productive tillers hill ⁻¹	Ear head length (cm)	No. of fingers ear head ⁻¹	1000 grain weight (g)	Ear head weight hill ⁻¹ (g)	Grain yield (q ha ⁻¹)	Stalk yield (q ha ⁻¹)	Harvest index
T ₁ - Absolute Control	3.07	5.10	3.10	2.44	4.17	15.88	20.69	0.44
T ₂ - RDF+FYM	5.26	6.47	6.60	4.36	8.32	35.89	41.91	0.46
T ₃ - RDF+ EPS @ 125 kg ha ⁻¹	4.12	5.62	5.05	3.09	6.61	28.30	34.37	0.45
T ₄ -RDF + EPS @ 250 kg ha ⁻¹	4.29	5.83	5.63	3.28	7.17	29.68	35.43	0.46
T ₅ - RDF + EPS @ 500 kg ha ⁻¹	4.40	6.23	5.34	3.65	7.47	32.76	35.62	0.48
T ₆ - RDF + EPS @ 750 kg ha ⁻¹	6.05	7.15	7.57	4.49	8.93	38.74	43.00	0.48
T ₇ - RDF + EPS @ 1000 kg ha ⁻¹	5.42	6.47	6.97	4.33	8.02	35.86	41.74	0.46
T ₈ - Balanced RDF + EPS @ 125 kg ha ⁻¹	4.03	5.41	5.08	3.07	6.18	23.84	33.43	0.42
T ₉ - Balanced RDF + EPS @ 250 kg ha ⁻¹	3.72	5.52	5.19	3.06	6.31	26.71	33.47	0.44
T ₁₀ - Balanced RDF + EPS @ 500 kg ha ⁻¹	4.13	5.63	5.14	3.13	6.72	29.99	36.41	0.45
T ₁₁ - Balanced RDF + EPS @ 750 kg ha ⁻¹	4.88	5.83	5.26	3.25	6.95	32.37	36.67	0.47
T ₁₂ - Balanced RDF + EPS @ 1000 kg ha ⁻¹	4.26	5.72	5.35	3.22	6.82	35.69	36.58	0.49
S.Em. ±	0.07	0.22	0.22	0.15	0.34	1.13	2.59	0.02
CD @ 5%	0.21	0.63	0.64	0.45	1.00	3.30	7.60	NS

Table 4: Effect of enriched phosphatic sludge application on nitrogen, phosphorus and potassium uptake (kg ha^{-1}) in finger millet during *kharif* 2016

Treatment	Nitrogen			Phosphorus			Potassium		
	(kg ha ⁻¹)								
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T ₁ - Absolute Control	22.55	20.84	43.39	3.65	3.31	6.96	4.25	18.79	23.04
T ₂ - RDF+FYM	64.57	47.39	111.97	10.09	7.99	18.07	14.42	44.67	59.09
T ₃ - RDF+ EPS @ 125 kg ha ⁻¹	43.16	36.92	80.08	6.81	5.85	12.67	8.67	33.91	42.58
T ₄ -RDF + EPS @ 250 kg ha ⁻¹	45.58	38.22	83.80	7.75	6.04	13.79	9.40	35.58	44.97
T ₅ - RDF + EPS @ 500 kg ha ⁻¹	46.63	39.90	86.53	8.07	6.45	14.52	9.77	39.54	42.55
T ₆ - RDF + EPS @ 750 kg ha ⁻¹	70.21	49.62	119.83	12.06	8.22	20.28	15.71	50.19	65.91
T ₇ - RDF + EPS @ 1000 kg ha ⁻¹	64.17	46.68	110.85	10.44	7.53	17.96	13.82	43.74	57.56
T ₈ - Balanced RDF + EPS @ 125 kg ha ⁻¹	36.07	33.77	69.84	5.01	5.37	10.37	7.87	35.32	43.19
T ₉ - Balanced RDF + EPS @ 250 kg ha ⁻¹	40.84	34.40	75.24	5.90	5.72	11.62	8.42	36.27	45.18
T ₁₀ - Balanced RDF + EPS @ 500 kg ha ⁻¹	46.03	37.67	83.70	7.22	6.59	13.81	9.81	39.90	48.56
T ₁₁ - Balanced RDF + EPS @ 750 kg ha ⁻¹	49.97	39.25	89.22	8.76	7.00	15.77	11.36	40.85	51.90
T ₁₂ - Balanced RDF + EPS @ 1000 kg ha ⁻¹	55.48	37.51	92.99	9.31	6.19	15.49	12.16	37.38	49.54
S.Em. ±	1.91	0.91	2.52	0.31	0.48	0.68	0.62	3.61	3.72
CD @ 5%	5.61	2.66	7.39	0.92	1.42	2.00	1.82	10.57	10.91

Table 5: Effect of enriched phosphatic sludge application on micro nutrient uptake (g ha^{-1}) in finger millet during *kharif* 2016

Treatment	Iron			Manganese			Copper			Zinc		
	(g ha ⁻¹)											
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T ₁ - Absolute Control	22.94	89.89	112.71	15.09	31.62	46.71	0.65	9.20	9.83	2.87	60.26	63.06
T ₂ - RDF+FYM	56.32	251.57	307.01	36.69	71.52	108.21	1.97	28.50	30.37	8.42	162.19	170.05
T ₃ - RDF+ EPS @ 125 kg ha ⁻¹	42.70	194.65	236.67	26.20	51.91	78.11	1.21	17.79	18.94	6.03	113.57	119.20
T ₄ -RDF + EPS @ 250 kg ha ⁻¹	45.02	201.95	246.26	27.65	54.47	82.13	1.38	18.60	19.92	6.62	121.77	127.97
T ₅ - RDF + EPS @ 500 kg ha ⁻¹	45.47	201.22	245.99	27.87	55.75	83.62	1.47	19.48	20.88	6.69	119.57	125.84
T ₆ - RDF + EPS @ 750 kg ha ⁻¹	62.34	269.77	331.17	40.62	74.69	115.31	2.34	30.61	32.85	10.83	175.48	185.69
T ₇ - RDF + EPS @ 1000 kg ha ⁻¹	56.89	259.49	315.48	37.02	70.96	107.98	2.03	25.67	27.61	9.45	159.47	168.37
T ₈ - Balanced RDF + EPS @ 125 kg ha ⁻¹	36.37	183.93	220.06	21.28	51.02	72.30	0.97	19.17	20.12	5.14	114.81	119.80
T ₉ - Balanced RDF + EPS @ 250 kg ha ⁻¹	41.03	187.65	228.03	24.58	52.20	76.78	1.11	19.53	20.57	5.98	118.87	124.44
T ₁₀ - Balanced RDF + EPS @ 500 kg ha ⁻¹	46.52	206.21	252.01	27.56	56.82	84.38	1.32	21.46	22.71	6.75	125.34	131.65
T ₁₁ - Balanced RDF + EPS @ 750 kg ha ⁻¹	50.31	210.64	260.21	29.96	58.99	88.95	1.50	21.76	23.18	7.34	124.15	131.05
T ₁₂ - Balanced RDF + EPS @ 1000 kg ha ⁻¹	55.97	198.85	254.12	33.22	55.70	88.92	1.70	20.66	22.29	8.20	121.81	129.59
S.Em. ±	1.71	3.91	15.90	1.42	1.11	1.79	0.08	0.65	1.95	0.28	2.34	9.58
CD @ 5%	5.01	11.46	46.63	4.17	3.27	5.25	0.24	1.91	5.73	0.82	6.86	28.11

Conclusion

In the entire study the results showed that growth parameters and yield parameters and uptake of major and micro nutrients in finger millet were recorded maximum in the treatment T₆ receiving RDF + EPS @ 750 kg ha⁻¹ followed by treatment T₇ receiving RDF + EPS @ 1000 kg ha⁻¹ and T₂ receiving RDF + FYM.

References

- Grobelak A, Placek A, Grosser A, Singh B, Kacprzak M. Effects of single sewage sludge application on soil phytoremediation. *Journal of Cleaner Production*. 2017;155:189-197.
- Herzel H, Kruger O, Hermann L, Adam C. Sewage sludge ash: A promising secondary phosphorus source for fertilizer production. *Science of the Total Environment*. 2015;542:1136-1143.
- Kumar C, Sharma SS. Effect of integrated nutrient management on growth, yield and quality of French bean variety Pant Anupama under valley conditions of Dehradun. *International Journal of Current Microbiology and Applied Sciences*. 2022;8(10):1950-1955.
- Khanmohammadi Z, Afyuni M, Mosaddeghi MR. Effect of sewage sludge and its biochar on chemical properties of two calcareous soils and maize shoot yield. *Archives of Agronomy and Soil Science*. 2017;63(2):198-212.
- Lavado RS. Effects of sewage sludge application on soils and sunflower yield: Quality and toxic element accumulation. *Journal of Plant Nutrition*. 2006;29:975-984.
- Latore AM, Kumar O, Singh SK, Gupta A. Direct and residual effect of sewage sludge on yield, heavy metals content and soil fertility under rice-wheat system. *Ecological Engineering*. 2014;69:17-24.
- Meena MC, Patel KP, Ramani VP. Effect of FYM and sewage sludge application on yield and quality of pearl millet-mustard cropping system and soil fertility in a Typic Haplustept. *Journal of the Indian Society of Soil Science*. 2013;61(1):55-58.
- Meena MC, Patel KP, Singh D, Dwivedi BS. Long-term effect of sewage sludge and farmyard manure on grain yields and availability of zinc and iron under pearl millet (*Pennisetum glaucum*)-Indian mustard (*Brassica juncea*) cropping sequence. *Indian Journal of Agricultural Sciences*. 2008;78(12):1028-1032.
- Singh RP, Agrawal M. Variations in heavy metal accumulation, growth and yield of rice plants grown at different sewage sludge amendment rates. *Ecotoxicology and Environmental Safety*. 2010;73(4):632-641.
- Singh R, Agrawal M. Effect of different sewage sludge applications on growth and yield of *Vigna radiata* L. field crop: Metal uptake by plant. *Ecological Engineering*. 2010;36:969-972.
- Zoubi MMA, Arslan A, Abdelgawad G, Pejon N, Tabbaa M, Jouzdan O. The effect of sewage sludge on productivity

- of a crop rotation of wheat, maize and vetch and heavy metals accumulation in soil and plant in Aleppo Governorate. *American-Eurasian Journal of Agricultural and Environmental Sciences*. 2008;3(4):618-625.
12. Yang GH, Zhu GY, Li HL, Han XM, Li JM. Accumulation and bioavailability of heavy metals in a soil-wheat/maize system with long-term sewage sludge amendments. *Journal of Integrative Agriculture*. 2018;17(8):1861-1870.