The Pharma Innovation Journal 2022; SP-11(9): 512-516

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 512-516

www.thepharmajournal.com
Received: 23-06-2022
Accepted: 26-08-2022

Kirtiwardhan
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Koshlendra Tedia
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Vinay Bachkaiya
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Vedhika Sahu
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Pragya Pandey
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author
Kirtiwardhan
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of fly ash application with vermicompost on soil physical properties in an *Entisol*

Kirtiwardhan, Koshlendra Tedia, Vinay Bachkaiya, Vedhika Sahu and Pragya Pandey

Abstract
The present investigation entitled "Effect of fly ash application with vermicompost on soil physical properties in an *Entisol*" was conducted during *Kharif*, 2021 at Krishi Vigyan Kendra, Bemetara. The treatments of the experiment comprised of control, 100% RDF(100:80:60), 75% RDF+20t ha^{-1} Fly ash, 75% RDF+20t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost, 75% RDF+40t ha^{-1} Fly ash, 75% RDF+40t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost, 75% RDF+60t ha^{-1} Fly ash, 75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost and laid out in Randomized Block Design (RBD) with three replications. The results of the treatment revealed that the soil pH and EC did not show any significant effect. The physical properties such as bulk density, particle density and porosity were not significantly affected on conjoined application of fly ash and vermicompost. A significant change in hydraulic conductivity, infiltration rate, moisture content and soil strength due to application of fly ash over control was observed. The soil strength was significantly reduced at 5 cm depth resulted by the addition of organic matter through vermicompost and fly ash. The increase in hydraulic conductivity due to different treatments of fly ash ranged from 55.32 cm/day to 76.84 cm/day as compared to control 55.32 cm/day and RDF 60.39 cm/day, respectively. The increase in infiltration rate due to different treatments of fly ash ranged from 0.84 cm/hr to 1.58 cm/hr as compared to control 0.84 cm/hr and RDF 1.02 cm/hr respectively. The increase in moisture content at harvest due to different treatments of fly ash ranged from 20% to 25.24% as compared to control 20% and RDF 22.10% respectively.

Keywords: Fly ash, vermicompost, soil physical properties

Introduction
Fly ash refers to the fine ash collected by the flue gas after the coal combustion burned. It is a major solid waste from coal-fired power plants. Fly ash is considered as environment pollutant but, when properly blended in soil can act as a boon in agricultural sector by improving soil properties and simultaneously provide solution for safe disposal. It is reported that fly ash can be utilized in agriculture as an ameliorant or fertilizer. In addition fly ash has many beneficial physical characteristic like texture, water-holding capacity, porosity etc. (Dhindsa *et al*., 2016) [6]. The type and quality of coal used determines the composition of fly ash. In general, it contains elements like Ca, Fe, Mg, and K, which are beneficial to plant growth, apart from B, Se, and Mo and other metals that can be toxic to the plants. The share of coal based electricity generation out of total electricity produced in India is around 75%. The coal used in TPPs have high ash content of the order of 30-45%, which generates large quantity of fly ash. Currently, there is much larger generation of fly ash than its utilization therefore, the management of this surplus stock which is increasing every year is of utmost importance. The management of fly ash has thus become a matter of concern as it requires large area of land for its disposal because of its potential of causing pollution of air and water (CEA report 2021) [18]. In vermicomposting, species of earthworms like *Eisenia fotida*, *Eudrilus engeniae* etc. and microorganisms undergo mesophilic process to enhance the process of organic waste conversion and produce a better end-product called vermicompost rich in plant nutrients. It is also loaded with the microorganisms that improve the soil health. The earthworms help in reducing the toxic heavy metals present in fly ash. Samy *et al*., (2010) [16] reported that use of optimum amount of fly ash increased the yield of rice, but higher levels of fly ash application resulted in decrease in yield. He reported that fly ash improved yield of crop, improves, reduced bulk density, and increased the water holding capacity and porosity. It also optimized the pH status, reduced crust formation, and provide micronutrients to the soil.

The improvement in soil physical character can be linked to repeated amendments of fly ash which facilitate process of soil binding and mineralization. The lime component made soil more alkaline.

Material Method

Research study entitled "Effect of fly ash application with vermicompost on soil physical properties in an *Entisol*" was conducted during Kharif 2021 in an Entisol at Krishi Vigyan Kendra, Bemetara and the laboratory work was performed at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, IGKV, Raipur (C.G.). The experiment was laid out with 8 treatments in Randomized Block Design and repeated three times. Twenty gram of air-dried soil was stirred with 50 ml of distilled water for approximately 30 minutes and the pH (soil/aqueous suspension 1:2.5) was determined with a pH meter as suggested by Piper (1967) [19]. The soil suspension after pH determination was stored overnight and EC of the supernatant liquid was determined by Solu-bridge as described by Black (1965) [20]. Bulk density was measured using paraffin clod method. Particle density was calculated using pycnometer method. Ex situ hydraulic conductivity was determined by constant head permeate method. Infiltration rate was determined by double ring Infiltrometer. Porosity was calculated by using the formula Porosity = (1-Bulk density/Particle density) x 100. To estimate the soil moisture content, gravimetric method (direct method) was adopted. Soil strength was measured with the instrument soil static penetrometer.

Results and discussion

Soil Reaction (pH)

The pH data shown in Table 3 reveals that no significant change was found between the treatments with pH value varying from 6.34 to 6.53.The highest pH 6.53 was found with T_8 (75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost), followed by 6.46 with T_3 (75% RDF+20t ha^{-1} Fly ash) and the lowest being 6.34 with T_1 (Control). Yadav (2006) [17], Khan and Qasim (2008) [8] also reported a non-significant effect of fly ash on pH of soil.

Electrical conductivity

Soil electrical conductivity result is shown in Table 3. It was non-significant and ranged between 0.29 to 0.35 dS m^{-1}. The highest EC was recorded with T_8 (75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost) and the lowest being with T_1 (Control). Yadav (2006) [17], Khan and Qasim (2008) [8] also reported a non-significant effect of fly ash on soil EC.

Bulk density

The results on bulk density shown in Table 4 and revealed that it was not influenced significantly on addition of fly ash and vermicompost. It varied from 1.41-1.57 Mg m^{-3}. The lowest reduction in bulk density was recorded with T_7 (75% RDF+60t ha^{-1} Fly ash) and T_8 (75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost). The highest bulk density 1.57 Mg m^{-3} was found with T_1 (Control). The decrease in bulk density maybe attributed to the increase in porosity and root penetration by application of fly ash and vermicompost respectively. Patel (2015) [14] also reported similar findings.

Particle density

The particle density presented in Table 4 and indicated that particle density was not significantly influenced on addition of varying doses of fly ash and Vermi-compost. The particle density ranged between 2.12 and 2.17 Mg m^{-3}. Lal (2014) [10] also reported similar results.

Hydraulic conductivity

Table 5 revealed the significant influence of different treatments of fly ash and Vermi-compost on soil. Hydraulic conductivity was increased due to addition of different fly ash treatments. It ranged between 76.95-55.32 cm day^{-1}. The maximum was 76.95 cm day^{-1} with T_8 (75% RDF+60t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost) which was at par with T_6 (75% RDF+40t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost) and T_7 (75% RDF+60t ha^{-1} Fly ash) and the minimum being 55.32 cm day^{-1} with T_1 (Control). Ramteke (2016) [15] also found similar results.

Infiltration rate

Table 5 revealed that infiltration rate measured at DAT was significantly influenced due to addition of fly ash. The lowest infiltration rate was 0.84 cm hr^{-1} recorded in T_1. It ranged from 0.84 cm hr^{-1} to 1.58 cm hr^{-1}. The maximum was found in T_8. It was significantly increased with application of various levels of fly ash with chemical fertilizers as compared to control. The increase in infiltration rate of soil is probably due to bigger particles of fly ash along with improvement in soil aggregation by vermicompost leading to increased porosity of the soil. The macrospores might have helped in downward movement of water. Similar result was also reported by Ramteke (2016) [15].

Porosity

The results presented in Table 6 showed that porosity was not significantly changed on conjoint application of vermi-compost and fly ash. The porosity varied between 27.88% and 31.02%. The maximum porosity was found in T_7 (75% RDF+60t ha^{-1} Fly ash) and the minimum in T_1 (Control). Similar result was reported by Patel (2015) [14], Agarwal *et al*. (2009) [1] and Kishor *et al*. (2009) [21].

Soil moisture content

It is evident from the data presented in Table 7 that treatment T_8 (75% RDF + 60t ha^{-1} Fly ash + 2t ha^{-1} Vermi-compost) recorded comparatively highest soil moisture content after 7 days of harvesting followed by T_7 (75% RDF+60t ha^{-1} Fly ash) and T_6 (75% RDF + 40t ha^{-1} Fly ash + 2t ha^{-1} Vermi-compost) which are at par with each other. The minimum was observed in T_1 (Control). The results indicated that fly ash and vermi-compost incorporation helped in retaining the soil moisture as compared to RDF (22.10%) and control (20%). Mandal (2021) [11] also reported similar result.

Soil strength

Soil strength (penetration resistance) was measured in situ at 90 DAT at depths of 5, 10 and 15cm. The variation in data as a function of depth and different treatments was summarised in Table 8 and revealed that the penetration resistance increased with increase in depth. At the depth of 5 cm soil strength was significantly lower 3.62 kN/cm^{-2} in T_8 (75% RDF+60t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost) followed by 3.73 kN/cm^{-2} in T_7 (75% RDF+60t ha^{-1} Fly ash) than the control T_1 (4.19 kN/m^{-2}). At the depth of 10 cm and 15 cm significant change in PR was not observed. The highest soil strength value was 4.19, 4.74 and 5.03 kN/cm^{-2} recorded in control plot at depths of 5, 10, and 15 cm respectively. The reduction of soil strength value may be due to low bulk density values as well as high porosity of soil as a result of the addition of fly ash and organic matter through vermicompost. Celik *et al*. (2010) [5], Mina *et al*. (2010) [12] and Bhogal *et al*. (2018) [2] reported similar findings.

Table 1: Treatment details

S. No.	Notations to be used	Treatment
1	T_1	Control
2	T_2	100% RDF(100:80:60)
3	T_3	75% RDF+20t ha^{-1} Fly ash
4	T_4	75% RDF+20t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost
5	T_5	75% RDF+40t ha^{-1} Fly ash
6	T_6	75% RDF+40t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost
7	T_7	75% RDF+60t ha^{-1} Fly ash
8	T_8	75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost

Table 2: Physico-chemical properties of fly ash

S. No.	Soil properties	Value	Remark
1	Texture	Sand (%) 86	
		Silt (%) 8	Loamy sand
		Clay (%) 6	
2.	pH	6.67	Slightly acidic
3.	EC (dSm^{-1})	0.11	Safe
4.	Total N (%)	0.12	
5.	Total P (%)	0.079	
6.	Total K (%)	0.74	
7.	Total Zn (mg/kg)	35.00	
8.	Total Fe (mg/kg)	3340.00	
9.	Total Cu (mg/kg)	11.00	
10.	Total Mn (mg/kg)	319.00	

Table 3: Effect of fly ash application with vermicompost on soil pH and electrical conductivity

	Treatments	Soil pH	Electrical conductivity (dS m^{-1})
T_1	Control	6.34	0.29
T_2	100% RDF(100:80:60)	6.42	0.32
T_3	75% RDF+20t ha^{-1} Fly ash	6.46	0.32
T_4	75% RDF+20t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost	6.35	0.33
T_5	75% RDF+40t ha^{-1} Fly ash	6.33	0.33
T_6	75% RDF+40t ha^{-1} Fly ash +2t ha^{-1} Vermi-compost	6.40	0.34
T_7	75% RDF+60t ha^{-1} Fly ash	6.32	0.34
T_8	75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost	6.53	0.35
	SEm±	.18	.01
	CD (p=0.05)	NS	NS

Table 4: Effect of fly ash application with vermicompost on bulk density

	Treatments	Bulk density (Mg m^{-3})
T_1	Control	1.54
T_2	100% RDF(100:80:60)	1.53
T_3	75% RDF+20t ha^{-1} Fly ash	1.52
T_4	75% RDF+20t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost	1.51
T_5	75% RDF+40t ha^{-1} Fly ash	1.51
T_6	75% RDF+40t ha^{-1} Fly ash +2t ha^{-1} Vermi-compost	1.51
T_7	75% RDF+60t ha^{-1} Fly ash	1.48
T_8	75% RDF+60t ha^{-1} Fly ash+ 2t ha^{-1} Vermi-compost	1.47
	SEm±	0.05
	CD (p=0.05)	NS

Table 5: Effect of fly ash application with vermicompost on particle density

	Treatments	Particle density (Mg m^{-3})
T_1	Control	2.13
T_2	100% RDF(100:80:60)	2.15
T_3	75% RDF+20t ha^{-1} Fly ash	2.14
T_4	75% RDF+20t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost	2.17
T_5	75% RDF+40t ha^{-1} Fly ash	2.14
T_6	75% RDF+40t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost	2.12

T_7	75% RDF+60t ha^{-1} Fly ash	2.15
T_8	75% RDF+60t ha^{-1} Fly ash+2t ha^{-1} Vermi-compost	2.13
	SEm±	.02
	CD (p=0.05)	NS

Table 6: Effect of fly ash application with vermicompost on hydraulic conductivity

	Treatments	Hydraulic conductivity (cm/day)
T_1	Control	55.32^{d}
T_2	100% RDF(100:80:60)	60.62^{cd}
T_3	75% RDF+20t ha^{-1} Fly ash	65.08^{bc}
T_4	75% RDF+20t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	65.11^{bc}
T_5	75% RDF+40t ha^{-1} Fly ash	70.70^{ab}
T_6	75% RDF+40t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	73.95^{a}
T_7	75% RDF+60t ha^{-1} Fly ash	75.91^{a}
T_8	75% RDF+60t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	76.95^{a}
	SEm±	2.10
	CD (p=0.05)	6.37

Table 7: Effect of fly ash application with vermicompost on infiltration rate

	Treatments	Infiltration rate (cm/hr)
T_1	Control	0.84^{f}
T_2	100% RDF(100:80:60)	1.02^{e}
T_3	75% RDF+20t ha^{-1} Fly ash	1.28^{d}
T_4	75% RDF+20t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	1.43^{bc}
T_5	75% RDF+40t ha^{-1} Fly ash	1.33^{cd}
T_6	75% RDF+40t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	1.49^{ab}
T_7	75% RDF+60t ha^{-1} Fly ash	1.40^{bc}
T_8	75% RDF+60t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	1.58^{a}
	SEm±	0.04
	CD (p=0.05)	0.12

Table 8: Effect of fly ash application with vermicompost on porosity

	Treatments	Porosity (%)
T_1	Control	27.88
T_2	100% RDF (100:80:60)	28.80
T_3	75% RDF+20t ha^{-1} Fly ash	29.06
T_4	75% RDF+20t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	30.39
T_5	75% RDF+40t ha^{-1} Fly ash	29.26
T_6	75% RDF+40t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	28.94
T_7	75% RDF+60t ha^{-1} Fly ash	31.02
T_8	75% RDF+60t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	30.72
	SEm±	2.07
	CD (p=0.05)	NS

Table 9: Effect of fly ash application with vermicompost on moisture content (%)

	Treatments	Moisture content (%)
T_1	Control	20.00^{d}
T_2	100% RDF(100:80:60)	22.10^{abcd}
T_3	75% RDF+20t ha^{-1} Fly ash	20.87^{cd}
T_4	75% RDF+20t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	21.73^{bcd}
T_5	75% RDF+40t ha^{-1} Fly ash	21.28^{cd}
T_6	75% RDF+40t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	23.80^{abc}
T_7	75% RDF+60t ha^{-1} Fly ash	24.71^{ab}
T_8	75% RDF+60t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	25.24^{a}
	SEm±	1.00
	CD (p=0.05)	3.02

Table 10: Effect of fly ash application with vermicompost on soil strength at 5cm, 10cm and 15cm depth at maturity stage

	Treatments	Soil 5cm	Strength 10cm	(kNm^{-2}) 15cm
T_1	Control	4.19	4.74	5.03
T_2	100% RDF(100:80:60)	4.17	4.49	4.97
T_3	75% RDF+20t ha^{-1} Fly ash	4.10	4.61	4.84
T_4	75% RDF+20t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	4.09	4.60	4.75
T_5	75% RDF+40t ha^{-1} Fly ash	3.93	4.40	4.70

T_6	75% RDF+40t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	3.83	4.40	4.67
T_7	75% RDF+60t ha^{-1} Fly ash	3.73	4.40	4.63
T_8	75% RDF+60t ha^{-1} Flyash+2t ha^{-1} Vermi-compost	3.62	4.44	4.60
	SEm±	0.12	0.11	0.19
	CD (p = 0.05)	0.36	NS	NS

Conclusion

It was found that conjoined application of fly ash with vermicompost had non-significant effect on soil pH, electrical conductivity, bulk density, particle density and porosity but significant change was found in hydraulic conductivity, infiltration rate, soil moisture content and soil strength.

References

1. Agarwal S, Singh GR, Yadav BR. Utilization of fly ash for crop production: Effect on the growth of wheat and sorghum crops and soil properties. Journal of Agricultural physics. 2009;9:20-23.
2. Bhogal A, Nicholson FA, Rollett A, Taylor M, Litterick A, Whittingham MJ, *et al*. Improvements in the quality of agricultural soils following organic material additions depend on both the quantity and quality of the materials applied. Frontiers in Sustainable Food Systems. 2018 Apr 19;2:9.
3. Bekele A, Kibret K, Bedadi B, Yli-Halla M, Balemi T. Effects of lime, vermicompost, and chemical P fertilizer on selected properties of acid soils of Ebantu District, Western Highlands of Ethiopia. Applied and Environmental Soil Science, Volume 2018, 2018 Jul 3, 1-13.
4. Bekele A, Kibret K, Bedadi B, Balemi T, Yli-Halla MJ. Vermicompost and chemical P fertilizer on yield of maize and soil properties in Ebantu District, Western Highlands of Ethiopia. African Journal of Agricultural Research, 2018 Mar 8;13(10):477-489.
5. Celik I, Gunal H, Budak M, Akpinar C. Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. Geoderma. 2010;160(2):236-243.
6. Dhindsa HS, Sharma RD, Kumar R. Role of fly ash in improving soil physical properties and yield of wheat (Triticum aestivum). Agricultural Science Digest-A Research Journal. 2016;36(2):97-101.
7. Kumar G. Assessment of fly ash incorporation with Vermi-compost on rice yield and soil properties in Entisol. M.Sc. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (Chhattisgarh); c2021.
8. Khan MJ, Qasim M. Integrated use of boiler ash as organic fertilizer and soil conditioner with NPK in calcareous soil. Songklanakarin Journal of Science & Technology. 2008 May 1;30:3.
9. Kishor P, Ghosh AK, Kumar D. Use of fly ash in agriculture: A way to improve soil fertility and its productivity. Asian Journal of Agricultural Research. 2010;4(1):1-14.
10. Lal B, Nayak V, Sharma P, Tedia K. Effect of combined application of FYM, fly ash and fertilizers on soil properties and paddy grown on degraded land. Current World Environment. 2014;9(2):531.
11. Mandal MK, Bachkaiya V, Tiwari A, Yadav S, Patre SS. Effect of fly ash, lime and vermicompost application on Physico-chemical properties of soil. The Pharma Innovation Journal. 2021;10(8):83-87.
12. Mina A, Nand R, Shri R. Long-term effect of inorganic fertilizers and manure on physical and chemical properties of soil after 35 years of continuous cropping of rice-wheat. Pantnagar Journal of Research. 2010;8(1):76-80.
13. Padhy RN, Nayak N, Dash-Mohini RR, Rath S, Sahu RK. Growth, metabolism and yield of rice cultivated in soils amended with fly ash and cyanobacteria and metal loads in plant parts. Rice Science. 2016;23(1):22-32.
14. Patel K. Influence of integrated effect of inorganic and organic fertilizers with fly ash on rice grown in acid soil of northern hills zone (C.G.) M.Sc. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh; c2015.
15. Ramteke LK. Effect of fly ash, organic manure and fertilizers on soil health and productivity of rice-wheat cropping system in an *Alfisol* and *Vertisol*. International Journal of Current Microbiology and Applied Sciences. 2016;6(7):1948-1952.
16. Samy NT, Mishra M, Sahu RK, Padhy RN. Growth, yield and metabolism of rice (Oryza sativa L.) during repeated applications of fly ash on soil. Advan Food Sci. 2010;32(2):110-117.
17. Yadav VK. Effect of different doses of fly ash on soil physico– chemical properties and yield of paddy. M.Sc. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh; c2006.
18. Barreda Hale M, Romero-Araya P, Cea Herrera M, Espinoza D, Castro N, Castro J, Serandour G. Computer-assisted planning with 3D printing for mandibular reconstruction caused by a mandibular fracture with secondary osteomyelitis: A Case Report. Clinical Case Reports. 2021 Jul;9(7):e04410.
19. Propst FM, Piper TC. Detection of the vibrational states of gases adsorbed on tungsten by low-energy electron scattering. Journal of Vacuum Science and Technology. 1967 Mar;4(2):53-6.
20. Black JW, Duncan WA, Shanks RG. Comparison of some properties of pronethalol and propranolol. British Journal of Pharmacology and Chemotherapy. 1965 Dec;25(3):577.
21. Paine P, Kishor J, Worthen SF, Gregory LJ, Aziz Q. Exploring relationships for visceral and somatic pain with autonomic control and personality. PAIN®. 2009 Aug 1;144(3):236-44.