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Growth and Yield of Maize as Influenced by Application of Exhausted Fire-Extinguishing Powder as a Phosphorus Source

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Abstract

Exhausted fire-extinguishing powder (EFP), a byproduct of the fire extinguishing industry, offers a promising alternative to traditional phosphatic fertilizers in agriculture. EFP is categorized into three grades based on its mono ammonium phosphate content: Grade A (90%), Grade B (40%) and Grade C (0%). The safe disposal of EFP or direct use in agriculture is challenging because of its striking features of high hydrophobicity and fine grade powder. This study investigates the use of exhausted fire extinguishing powder as a source of phosphorus either directly or by compost enrichment technique. A field experiment was conducted during 2023 in GKVK, Bangalore, Karnataka, India to evaluate the effect of exhausted fire-extinguishing powder as phosphorus source on growth and yield parameters of maize plants using a randomized complete block design with ten treatments, including various bioenriched EFP composts and direct applications of different EFP grades. Results showed that significantly higher plant height (272.70 cm), number of leaves (14.13), number of kernels per cob (705.24), kernel yield (95.55 q ha^{-1}), stover yield (112.62 q ha^{-1}) and harvest index (0.45) were recorded in 100% NK + 50% RDP-CF + 50% RD-P using EFP (90%) + FYM on par with 100% NPK + 500 kg ha^{-1} EFP (0%) + FYM and 100% NK + 100 RDP-C_2 bioenriched EFP (90%) compost, while lowest were found in control treatment. This suggesting that EFP can be a viable substitute for conventional phosphorus fertilizers in maize cultivation, supporting more sustainable agricultural practices.

Keywords : Exhausted fire-extinguishing powder, Bioenriched EFP compost, Conventional fertilizer

Fire Extinguishing powders (EP) are the most common extinguishing agents and are composed of 40 to 50 per cent mono-ammonium phosphate (MAP), ammonium sulfate, coloring additives and fluxing agents. After its whole service life or expiry (36 months, under current legislation), the problem arises of how to manage the exhausted fire-extinguishing powders (EFP), allowing the recovery of a high-value, non-renewable raw material (phosphate) in an almost pure form (Pratico *et al.*, 2010). Being rich in phosphorus, the EFP can be used as an alternative source of phosphorus. Once freed from additives applied to guarantee flowability and water-repellent features, this material can be used in agriculture as, for example, fertilizer (Pratico *et al.*, 2010). Some farms distribute the extinguishing powders directly onto the field *via.,* a manure spreader (Dotelli and Vigano, 2020) but their efficiency is not guaranteed and can cause environmental problems because the microscopic dimensions of particles, with a variable range between 0.250 and 0.040 mm, can generate dust emissions, increasing the risk of respiratory symptoms (Chongyang *et al*., 2018).

The importance of recycling exhausted fire-extinguisher waste lies in its potential to serve as a secondary raw material when used for N and P recovery in line with the circular economy concept. This concept focuses on material and resource efficiency by transforming waste into products that can be utilized for other purposes (Robles *et al*., 2020). Such an approach is expected to enhance sustainable development and preserve virgin raw resources (*e.g*., P rocks), divert wastes from landfills, safeguard ecosystems, save energy and reduce greenhouse gas emissions. One possible solution is mixture with compost and other organic biomasses and agricultural residues. This approach not only improves nutrient availability but also mitigates disposal issues associated with EFP. This study aims to evaluate the impact of applying EFP, in both its raw and composted forms, on the growth and yield of maize (*Zea mays* L.). By investigating the effectiveness of EFP as a phosphorus source, this research seeks to contribute to sustainable maize production practices and the broader goal of recycling industrial byproducts in agriculture.

Material and Methods

A field experiment was carried out during *kharif* 2023 by using maize as test crop (MAH-15-84) at M-block of Agroforestry, UAS, GKVK, Bengaluru to know the performance of EFP and bioenriched pressmud compost from EFP on growth and yield of maize. The experiment consists of 10 treatments with three replications laid in completely randomized block design. The physical and chemical properties of soil were determined according to standard procedures as given in Table 1.

Table 1

Methods adopted for soil, EFP and compost analysis

Parameters	Methods	References
Physical properties		
Soil texture (%)	International pipette method	Piper (1966)
Bulk density (Mg m^{-3})	Keen Raczkowski cup method	Piper (1966)
Maximum water holding capacity (%)	Keen Raczkowski cup method	Piper (1966)
Chemical properties		
pH (1:2.5)	Potentiometric method	Jackson (1973)
EC (1:2.5)	Conductometric method	Jackson (1973)
Organic carbon (g kg^{-1})	Wet oxidation method	Walkley and Black (1934)
Available nitrogen (kg N ha^{-1})	Alkaline potassium permanganate Method	Subbiah and Asija (1956)
Available phosphorous (kg P_2O_5 ha^{-1})	Bray's extractant using spectrophotometer	Jackson (1973)
Available potassium (kg K_2O ha^{-1})	Ammonium acetate extractant using Flame photometery	Jackson (1973)
Available sulphur (mg kg^{-1})	Turbidometric method	Jackson (1973)
Exchangable calcium [c mol (p+) kg^{-1}]	Complexometric titration	Jackson (1973)
Exchangable magnesium [c mol (p+) kg^{-1}]	Complexometric titration	Jackson (1973)
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvel, (1978)

Continued....

TABLE 1 Continued....

Parameters	Methods	References
Biological properties		
Dehydrogenase activity (µg of TPFg^{-1} of soil 24 h^{-1})	Triphenyl Tetrazolium Chloride (TTC)	Casida (1964)
Acid phosphatase activity (µg of PNP g^{-1} of soil h^{-1})	Modified universal buffer and p- nitrophenol	Eivazi and Tabatabai (1977)
EFP		
Total phosphorus (P%)	Quinoline phosphomolybadte gravimetric analysis	Fertilizer control order (1985)
EFP bioenriched pressmud composts		
Total phosphorus (P%)	Vanadomolybdic yellow colour method	Piper (1966)

The experimental site was sandy clay loam in texture with 53.3, 22.5 and 24.2 per cent sand, silt and clay, respectively. It belongs to the *Isohyperthermic* family of the sub group *typic kandic paleustalfs*. The bulk density and maximum water holding capacity of the soil was 1.40 Mg m^{-3} and 34 per cent. The pH of the soil was 6.73 and low in soluble salts (0.12 dS m^{-1}). The soil was low in organic carbon (4.50 g kg^{-1}), low in available nitrogen (145.13 kg ha^{-1}), high in available P_2O_5 (83.93 kg ha^{-1}), medium in K_2O (271.49 kg ha^{-1}). While available sulphur content (16.92 mg kg^{-1}) was sufficient. The exchangeable calcium and magnesium content of soil was 2.60 and 1.72 cmol (p+) kg^{-1}, respectively. The content of DTPA extractable iron, manganese, zinc and copper was 16.40, 19.12, 3.47 and 1.10 mg kg^{-1}, respectively. The dehydrogenase and acid phosphatase activity were 14.50 µg of TPFg^{-1} of soil 24 h^{-1} and 42.07 µg of PNP g^{-1} of soil h^{-1}.

The three different grades of EFP *i.e.* 90 per cent (EFP_A), 40 per cent (EFP_B) and 0 per cent (EFP_C) were procured from Usha Armour Private Limited, located at Bangalore. These grades were classified based on the amount of Mono ammonium phosphate content in EFP. Different composts (four numbers) were prepared from EFP using pressmud and other additives *viz*., cowdung, microbial decomposer. Pressmud being rich in phosphorus (1.13%) was used as base material. For 1000 kg of pressmud, 100 kg of cow dung and 5 kg of microbial decomposer was added. EFP of different grades were added at the rate of 100 kg and mixed completely. After 3 months of composting microbial consortia 5 kg was added to the 1000 kg of matured compost. The EFP bio enriched pressmud compost was added to the field prior to sowing of maize. The treatment which received 100 per cent NPK + FYM @ 7.5 t ha^{-1} was considered as check.

TABLE 2

Different raw materials applied for different treatments and their phosphorus content

Raw materials	Quantity (kg)	Phosphorus content (P%)
EFP_A	79	20.90
EFP_B	270	6.09
EFP_C	500	0.93
C_1	2060	1.59
C_2	500	8.29
C_3	900	3.51
C_4	1000	3.05

The recommended dose of fertilizers for maize is 150:75:40 kg N, P_2O_5 and K_2O ha^{-1}. Recommended dose of nitrogen and potassium were applied through urea and muriate of potash commonly for all treatments except for T_{10}. Urea was applied in split

TABLE 3
Treatment details

T_1	: 100% NPK
T_2	: 100% NPK + FYM
T_3	: 100% NK + 100% RDP - C_1 bioenriched Pressmud compost
T_4	: 100% NK + 100% RDP - C_2 bioenriched EFP_A compost
T_5	: 100% NK + 100% RDP – C_3 bioenriched EFP_B compost
T_6	: 100% NK + 100% RDP – C_4 bioenriched EFP_C compost
T_7	: 100% NK + 50% RDP-CF + 50% RDP – EFP_A + FYM
T_8	: 100% NK + 50% RDP-CF + 50% RDP – EFP_B + FYM
T_9	: 100% NPK + 500 kg ha^{-1} EFP_C + FYM
T_{10}	: Absolute control

doses *i.e.*, 50 per cent of RD-N as basal dose and 25 per cent was applied after 30 DAS and remaining 25 per cent at 50 DAS. Recommended dose of phosphorus was applied through Single Super Phosphate for T_1, T_2 and T_9, while for treatments T_3, T_4, T_5 and T_6 applied through different composts based on P content. For treatments T_7 and T_8, 50 per cent recommended P was applied through SSP and remaining 50 per cent P through direct application of EFP_A and EFP_B, respectively for T_7 and T_8 treatments based on P content. FYM @ 7.5 t ha^{-1} was applied for T_2, T_7, T_8 and T_9 treatments.

Observations on growth parameters of maize such as plant height and number of leaves per plant were recorded at 30, 60, 90 DAS and at harvest from five tagged plants. Yield parameters such as cob length, number of kernels per cob and test weight (grams) were recorded at harvest from ten plants. Kernel and stover yield of maize were recorded from ten plants after reaching physiological maturity and computed to plant population. Harvest index was worked out by using following formula.

$$\text{Harvest index} = \frac{\text{Kernel yield (q } ha^{-1}\text{)}}{\text{Kernel yield (q } ha^{-1}\text{)} + \text{Stover yield (q } ha^{-1}\text{)}}$$

The price of inputs that were prevailing at the time of their use was considered to work out cost of cultivation. Treatment wise cost of cultivation was worked out. Net return per hectare was calculated by deducting the cost of cultivation from gross income. Benefit cost ratio was also computed.

For the interpretation of results, data obtained in the studies were subjected to statistical analysis using technique of analysis of variance for randomised block design as outlined by Gomez and Gomez (1984). The level of significance used in ‘F’ and ‘t’ test was P = 0.05. Critical difference (CD) values were calculated for the P = 0.05 whenever ‘F’ test was found significant.

RESULTS AND DISCUSSION

Growth Parameters of Maize

The data on plant height (cm) and number of leaves per plant of maize at different stages of crop growth period (30 DAS, 60 DAS, 90 DAS and at harvest) as influenced by the application of EFP and EFP bioenriched pressmud compost are presented in Table 4 and 5.

Plant Height

The data from the Table 4 it was revealed that, at 30 DAS, significantly higher plant height (55.9 cm) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (55.1 cm) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (55.0 cm), whereas significantly lowest plant height (37.1 cm) was recorded in the absolute control. The significantly higher plant height at 60 and 90 DAS (189.8 and 269.7 cm) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (180.8 and 260.8 cm) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (178.8 and 258.8 cm), whereas significantly lowest plant height (129.8 and 201.4 cm) was recorded in the absolute control. The plant height at harvest recorded significantly higher (272.3 cm) in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (263.7 cm) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (261.7 cm), whereas significantly lowest plant height (212.6 cm) was recorded in the absolute control.

TABLE 4

Plant height (cm) at different growth stages of maize as affected by application of different grades of EFP and EFP bio enriched pressmud composts

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	43.8	148.3	224.9	227.2
T_2	53.2	177.8	257.8	260.7
T_3	48.3	153.8	233.8	236.7
T_4	55.0	178.8	258.8	261.7
T_5	52.4	169.1	249.1	252.2
T_6	49.9	161.5	241.5	244.4
T_7	55.9	189.8	269.7	272.3
T_8	52.8	175.8	255.8	258.9
T_9	55.1	180.8	260.8	263.7
T_{10}	37.1	129.8	201.4	212.6
S.Em. ±	2.11	7.14	7.31	4.61
CD at 5%	6.26	21.23	21.71	13.69

Number of Leaves Per Plant

The data on number of leaves are presented in Table 5 and it revealed that at 30 DAS, significantly higher number of leaves per plant (7.33) was recorded in 100% NK + 50% RDP - CF + 50% RDP – EFP_A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (7.27) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (7.13), whereas significantly lowest number of leaves (4.92) was recorded in the absolute control. The significantly higher number of leaves at 60 and 90 DAS (13.83 and 14.53) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (13.77 and 14.47) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (13.63 and 14.33), whereas significantly lowest number of leaves (8.62 and 8.92) was recorded in the absolute control. The plant at harvest indicated that, significantly higher number of leaves (14.13) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP-A + FYM followed at par with 100% NPK + 500 kg ha^{-1} EFP_C + FYM (14.07) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (13.93), whereas significantly lowest number of leaves (8.52) was recorded in the absolute control.

Among the different composts used as a source of phosphorus, application of EFP_A bioenriched pressmud compost resulted in higher plant height and number of leaves (261.7 cm and 13.93) followed by EFP_B bioenriched pressmud compost (252.2 cm and 13.56) and EFP_C bioenriched pressmud compost (244.4 cm and 13.20) at harvest stage. However, EFP_A and EFP_B bioenriched pressmud compost treatments were on par with the 100% NPK + FYM (260.7 cm and 13.68).

Among the direct application of different grades of EFP used as a source of phosphorus, application of 50% RDP - CF + 50% RDP - EFP_A + FYM resulted in higher plant height and number of leaves (272.3 cm and 14.13) followed by 100% NPK + 500 kg ha^{-1} EFP_C + FYM (263.7 cm and 14.07) and 50% RDP - CF + 50% RDP - EFP_B + FYM *i.e.*, 258.9 cm and 13.64 at harvest stage. However, all these treatments were on par with the 100% NPK + FYM (260.7 cm and 13.68).

TABLE 5

Number of leaves at different growth stages of maize as affected by application of different grades of EFP and EFP bioenriched pressmud composts

Treatments	Number of leaves			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	6.19	11.75	12.20	11.62
T_2	7.07	13.57	14.07	13.68
T_3	6.40	12.90	13.06	12.66
T_4	7.13	13.63	14.33	13.93
T_5	6.87	13.37	13.98	13.56
T_6	6.60	13.10	13.60	13.20
T_7	7.33	13.83	14.53	14.13
T_8	6.87	13.37	14.01	13.64
T_9	7.27	13.77	14.47	14.07
T_{10}	4.92	8.62	8.92	8.52
S.Em. ±	0.29	0.56	0.58	0.58
CD at 5%	0.87	1.67	1.74	1.73

Irrespective of grades application of EFP along with SSP (50% RDP each) increased the plant height and number of leaves of maize. The increase might be due to better P availability and uptake of P which might have caused greater cell elongation and cell multiplication. The added advantage of mixing SSP with EFP is that, P being essential for the growth of crop throughout its growth period, SSP satisfies the initial requirement of crop by immediate dissolution while, EFP will undergo slow dissolution and maintains higher phosphorus availability in soil at later stages of crop growth and enhances the P uptake even at later stages of crop growth (Black, 1968). Biju (1994) and Kulkarni (1995) also reported the similar findings of increased plant growth parameters with application of rock phosphate along with pyrite and phosphate solubilizing bacteria which might be due to increased availability of P through solubilization by H_2SO_4 produced by biological oxidation of pyrite. The higher plant growth parameters of maize were observed in 100% RDP + 500 kg ha^{-1} of EFP_C which might be due to additional phosphorus along with other essential nutrients application through EFP_C along with RDP.

The increase in the plant growth parameters of the maize in EFP bioenriched pressmud compost treated plots was mainly due to increased availability of nutrients from bioenriched compost and mineralization. Hence, there was increase in vegetative growth of the plant, enhanced sugar translocation and turgor pressure in plant cell that leads to cell enlargement and multiplication. Similar results were reported by Solaimalai *et al*. (2001) and Abbasi *et al*. (2014). Reduced plant height and number of leaves in absolute control was due to inadequate supply of required plant nutrients.

Yield Parameters of Maize

The data recorded with respect to yield parameters *viz*., cob length, number of kernels per cob and test weight at harvest as influenced by application of EFP and bioenriched pressmud composts varied significantly and are presented in Table 6.

Cob Length

Significantly higher cob length (19.85 cm) was recorded in 100% NK + 50% RDP - CF + 50% RDP – EFP_A + FYM followed at par with the 100% NPK +

TABLE 6

Yield parameters of maize as affected by application of EFP and EFP bioenriched pressmud composts

Treatments	Cob length (cm)	No. of kernels per cob	Test weight (g)
T_1	17.30	531.49	29.59
T_2	19.15	610.65	34.18
T_3	18.50	545.86	32.59
T_4	19.25	614.33	34.55
T_5	19.02	548.17	33.48
T_6	18.75	546.94	33.25
T_7	19.85	705.24	36.65
T_8	19.02	558.84	34.00
T_9	19.52	673.86	34.82
T_{10}	12.62	273.04	23.64
S.Em. ±	0.54	25.39	1.49
CD at 5%	1.60	75.43	4.44

500 kg ha^{-1} EFP_C + FYM (19.52 cm) and 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (19.25 cm), where as significantly lowest cob length of maize (12.62 cm) was recorded in the absolute control.

Number of Kernels Per Cob

Significantly higher number of kernels per cob (705.24) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with the 100% NPK + 500 kg ha^{-1} EFP_C + FYM (673.86) and 100% NK + 100% RDP - C_2 bioenriched EFP_A compost pressmud (614.33), whereas significantly lowest number of kernels per cob (273.04) was recorded in the absolute control.

Among the different composts used as a source of phosphorus, application of EFP_A bioenriched pressmud compost resulted in higher cob length and number of kernels per cob (19.25 cm and 614.33) followed by EFP_B bioenriched pressmud compost (19.02 cm and 548.17) and EFP_C bioenriched pressmud compost (18.75 cm and 546.94). However, all these compost treatments were on par with the 100% NPK + FYM (19.15 cm and 610.65).

Among the different grades of EFP used as a source of phosphorus, application of 50% RDP - CF + 50% RDP - EFP_A + FYM resulted in higher cob length and number of kernels per cob (19.85 cm and 705.24) followed by 100% NPK + 500 kg ha^{-1} EFP_C + FYM (19.52 cm and 673.86) and 50% RDP - CF + 50% RDP - EFP_B + FYM *i.e.*, 19.02 cm and 558.84. However, all these treatments were on par with the 100% NPK + FYM (19.15 cm and 610.65).

Cob length and number of kernels per cob were recorded higher in 50% RDP - EFP + 50% RDP - SSP and EFP bioenriched pressmud compost could be ascribed to the slow and steady rate of nutrient release into the soil pool to match the higher adsorption pattern of maize. The higher cob parameters of maize were observed in 100% RDP + 500 kg ha^{-1} of EFP_C treated plots, which might be due to additional phosphorus and other nutrients application along with RDP.

Test Weight

Significantly higher test weight of maize (36.65 g) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with the 100% NPK + 500 kg ha^{-1} EFP_C + FYM (34.82 g) and 100% NK + 100% RDP - C_2 bioenriched EFP_A compost (34.55 g), whereas significantly lowest test weight of maize (23.64 g) was recorded in the absolute control.

Application of EFP in combination with SSP increased the test weight of maize significantly due to higher P uptake by maize may be due to solublization of insoluble P in EFP by SSP. These results were similar with findings of Mishra *et al*. (1980) with respect to rock phosphate.

Yield of Maize

The data recorded with respect to kernel and stover yield of maize as influenced by application of EFP and EFP bioenriched pressmud composts varied significantly and are presented in Table 7.

Significantly higher kernel yield (95.55 q ha^{-1}) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM followed at par with the 100%

TABLE 7

Kernel yield, stover yield and harvest index of maize as affected by application of EFP and EFP bioenriched pressmud composts

Treatments	Kernel yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index
T_1	80.31	95.58	0.46
T_2	91.67	108.50	0.46
T_3	85.55	102.63	0.45
T_4	92.22	109.35	0.46
T_5	89.43	106.69	0.46
T_6	87.22	104.88	0.45
T_7	95.55	112.63	0.46
T_8	90.55	107.41	0.46
T_9	94.91	111.81	0.46
T_{10}	50.36	86.66	0.37
S.Em. ±	3.45	2.46	0.01
CD at 5%	10.26	7.31	NS

NPK + 500 kg ha^{-1} EFP$_C$ + FYM (94.91 q ha^{-1}), 100% NK + 100% RDP - C_2 bioenriched EFP$_A$ pressmud compost (92.22 q ha^{-1}), T_2 (91.67 q ha^{-1}), T_8 (90.55 q ha^{-1}) and T_5 (89.43 q ha^{-1}), whereas significantly lowest kernel yield (50.36 q ha^{-1}) was recorded in the absolute control. Significantly higher stover yield (112.63 q ha^{-1}) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP$_A$ + FYM followed at par with the 100% NPK + 500 kg ha^{-1} EFP$_C$ + FYM (111.81 q ha^{-1}), 100% NK + 100% RDP - C_2 bioenriched EFP$_A$ pressmud compost (109.35 q ha^{-1}), T_2 (108.50 q ha^{-1}), T_8 (107.41 q ha^{-1}), T_5 (106.69 q ha^{-1}) and T_6 (104.88 q ha^{-1}), whereas significantly lowest stover yield (86.66 q ha^{-1}) was recorded in the absolute control.

Among the different composts used as a source of phosphorus, application of EFP$_A$ bioenriched pressmud compost resulted in higher kernel and stover yield (92.22 and 109.35 q ha^{-1}, respectively) followed by EFP$_B$ bioenriched pressmud compost (89.43 and 106.69 q ha^{-1}, respectively) and EFP$_C$ bioenriched pressmud compost (87.22 and 104.88 q ha^{-1}, respectively). However, all these compost treatments were on par with the 100% NPK + FYM (91.67 and 108.50 q ha^{-1}).

Among the different grades of EFP used as a source of phosphorus, application of 50% RDP - CF + 50% RDP - EFP$_A$ + FYM resulted in higher kernel and stover yield (95.55 and 112.63 q ha^{-1}, respectively) followed by 100% NPK + 500 kg ha^{-1} EFP$_C$ + FYM (94.91 and 111.81 q ha^{-1}, respectively) and 50% RDP - CF + 50% RDP - EFP$_B$ + FYM *i.e.* 90.55 and 107.41 q ha^{-1}. However, all these treatments were on par with the 100% NPK + FYM (91.67 and 108.50 q ha^{-1}, respectively).

Application of EFP in combination with SSP increased the kernel and stover yield of maize significantly. The increase in yield of maize may be attributed to SSP, wherein P being in immediately available form can satisfy the initial need of the crop while and acts as booster dose. While EFP being slow in dissolution can maintain higher phosphate potential in soil throughout the crop growth. Similar results of increased yield by application of combined use of water soluble and insoluble sources in 1:2 proportion were reported by Talashilkal and Patil (1979) and Krishnappa *et al.* (1991). The higher kernel and stover yield of maize were observed in 100% RDP + 500 kg ha^{-1} of EFP$_C$ treated plots, which might be due to additional phosphorus application along with RDP.

The positive effect of increase in kernel and stover yield of maize by the application of EFP bioenriched pressmud compost was observed. This might be due to continuous and greater availability of soil nutrients throughout the crop growth under enriched compost along with NK and uptake of nutrients by crop as revealed by the increased growth parameters and cob parameters might have resulted in increased kernel yield of maize (Imam & Sharanappa, 2002; Shanmugam & Veeraputhran, 2000; Lavanya & Sathish, 2020 and Pooja & Sathish, 2023).

Harvest Index

There was no significant difference observed for harvest index between the treatments due to application of different grades of EFP and EFP bioenriched pressmud compost (Table 7). However, higher harvest index (0.46) was recorded in 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM, 100% NPK + 500 kg ha^{-1} EFP_C + FYM, 100% NK + 50% RDP - CF + 50% RDP - EFP_B + FYM, 100% NK + 100% RDP - C_2 bioenriched EFP_A compost and 100% NK + 100% RDP - C_3 bioenriched EFP_B compost whereas lowest harvest index of maize (0.37) was recorded in the absolute control.

There was a proportionate increase in both kernel and stover yields of maize with EFP bioenriched composts and direct EFP application, thus resulting in non-significant harvest index. Similar results were also obtained by Patil and Shete (2008).

Economics

Economics of maize production as influenced by application of EFP and EFP bioenriched pressmud composts is presented in Table 8.

Higher cost of cultivation was recorded in T_9 (Rs.76926) followed by T_2 (Rs.75426) and lower cost of cultivation was observed in T_{10} (Rs.54360). The higher gross return was recorded in treatment T_7 receiving 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM (Rs.2,23,872) followed by T_9: 100% NPK + 500 kg ha^{-1} EFP_C + FYM (Rs.2,22,347) and T_4: 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (Rs.2,16,127). The least gross return was recorded in T_{10}: Absolute control plot (Rs.1,20,716). The higher net returns was recorded in treatment T_4 receiving 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost (Rs.1,53,661) followed by T_7: 100 % NK + 50% RDP - CF + 50% RDP - EFP_A + FYM (Rs.1,50,464) and T_9: 100% NPK + 500 kg ha^{-1} EFP_C + FYM (Rs.1,45,421). The least net returns was recorded in T_{10}: Absolute control plot (Rs.66,356).

The higher B:C ratio of 3.46 was recorded in treatment receiving T_4: 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost and it was followed by treatment T_5: 100% NK + 100% RDP - C_3 bioenriched EFP_B pressmud compost (3.24) and T_7: 100 % NK + 50% RDP - CF + 50% RDP - EFP_A + FYM (3.05). Whereas, the least B:C ratio (2.22) was observed in the treatment T_{10}: Absolute control plot where no manures and fertilizers were given.

The higher B:C ratio noticed in EFP enriched composts treatment might be attributed to lower cost of cultivation and also due to higher kernel and stover yield. Similar views were expressed by Ramateke *et al*. (1998) and Yogananda *et al*. (2010).

TABLE 8

Economics of maize production as influenced by application of EFP and EFP bioenriched pressmud composts

Treatments	COC (Rs.)	Gross Returns (Rs.)	Net Returns (Rs.)	B:C Ratio
T_1	64176	188247	124071	2.93
T_2	75426	214808	139382	2.85
T_3	68860	200621	131761	2.91
T_4	62466	216127	153661	3.46
T_5	64648	209639	144991	3.24
T_6	66960	204555	137595	3.05
T_7	73408	223872	150464	3.05
T_8	74238	212224	137986	2.86
T_9	76926	222347	145421	2.89
T_{10}	54360	120716	66356	2.22

Exhausted fire-extinguishing powder, a waste from fire-extinguishing industry can be used for improving growth and yield of maize. Among the P sources evaluated EFP along with combination of SSP (1:1) was the best P source for Maize. The EFP bioenriched composts produced with pressmud would enhance the sustained release of nutrients through various mechanisms. From the results obtained, it can be concluded that the treatments with T_7: 100% NK + 50% RDP - CF + 50% RDP - EFP_A + FYM, T_9: 100% NPK + 500 kg ha^{-1} EFP_C + FYM and T_4: 100% NK + 100% RDP - C_2 bioenriched EFP_A pressmud compost were showed higher growth and yield of maize. The different grades of EFP used in combination with SSP and EFP bioenriched composts as a source of phosphorus were found better in terms of improving the performance of maize productivity and were on par with the 100% NPK + FYM. This suggesting EFP could be viable substitute for conventional phosphatic fertilizer.

References

Abbasi, G., Anwar, U. H., Moazzam, J., Muhammad, A. U. H., Shafaqat, A., Ahmad, M., Akhtar, F., Muhammad, A. I., Hamid, N. K. and Muhammad, A. K., 2014, Enhancement of maize production through integrated plant nutrient management in arid climate. *J. Pure App. Sci.*, **24 - 33** (1-2) : 7 - 16.

Biju, J., 1994, Studies on phosphorus in soybean - wheat crop sequence in *Vertisols*. *M. Sc.(Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

Black, C. A., 1968, Soil plant relations. Phosphorus functions in plants. John Willey and Sons Publications, pp. : 626.

Casida, L. E., Klein, D. A. and Santaro, T., 1964, Soil dehydrogenase activity. *Soil Sci.,* **96** : 371 - 376.

Chongyang, L., Daniel, A. B. and Sanjai, J. P., 2018, Estimating potential dust emissions from biochar amended soils under simulated tillage. *Sci. Total Environ.,* **625** : 1093 - 1101.

Dotelli, G. and Vigano, E., 2020, Phosphate recovery from exhausted extinguishing powders: A case study of circular economy in the chemical industry. In *life cycle assessment 0in the chemical product chain*, pp. : 145 - 165.

Eivazi, F. and Tabatabai, M. A., 1977, Phosphatases in soils. *Soil Boil. Biochem.,* **9** (3) : 167 - 172.

Fertilizer Control Order, 1985, Ministry of Chemicals and Fertilizers. Government of India.

Gomez, K. A. and Gomez, A. A., 1984, Statistical procedures for agricultural research. John Wiley and Sons, New York.

Imam, A. K. and Sharanappa, 2002, Growth and productivity of maize (*Zea mays* L.) as influenced by poultry waste composts and fertilizer levels. *Mysore J. Agric. Sci*., **36** : 203 - 207.

Jackson, M. L., 1973, *Soil Chemical Analysis*, Prentice Hall of India private limited, New Delhi. pp. : 485.

Krishnappa, K. M., Panchaksharaiah, S., Sharma, K. M. S., Vageesh, T. S., Wright, R. J., Baligar, V. C. and Murrmann, R. P., 1991, Efficiency of RP in rice-groundnut cropping system in acidic soils of coastal Karnataka, India. *Developments Plants Soil Sci.*, **45** : 533 - 538.

Kulkarni, 1995, Studies on efficiency of different sources of phosphorus in chickpea. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

Lavanya, G. and Sathish, A., 2020, Effect of phosphorus enriched biocompost on nutrient use efficiency, growth and yield of Finger Millet (*Eleusine coracana G.*). *Mysore J. Agric. Sci*., **54** (2) : 77 - 80.

Lindsay, W. L. and Norvell, W. A., 1978, Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. Am. J.,* **42** : 421 - 428.

Mishra, B., Sharma, R. D. and Mishra, N. P., 1980, Use of mussoorie rock phosphate mixed with superphosphate for wheat on neutral soils. *Indian J. Agric. Sci*., **50** (4) : 346 - 351.

Patil, H. M. and Shete, B. T., 2008, Integrated nutrient management in pigeon pea-pearl millet intercropping system under dryland conditions. *J. Maharashtra Agric. Univ*., **33** (1) : 119 - 120.

PIPER, C. S., 1966, *Soil and Plant Analysis*, Hans Publishers, Bombay, pp. : 368.

POOJA, S. P. AND SATHISH, A., 2023, Effect of application of blended granite rock dust with solid and liquid organic manures on yield of Maize (*Zea mays* L.). *Mysore J. Agric. Sci.,* **57** (1) : 251 - 262.

PRATICO, F. G., MORO, A. AND AMMENDOLA, R., 2010, Potential of fire extinguisher powder as a filler in bituminous mixes. *J. Hazard Mater.*, **173** : 605 - 613.

RAMATEKE, J. R., MAHADKAR, U. V. AND YADAV, R. S., 1998, Sustainable crop production through cropping system and organic farming. *In: Int. Agron. Cong*., pp. : 393 - 394.

ROBLES, A., AGUADO, D., BARAT, R., BORRAS, L., BOUZAS, A., GIMENEZ, J. B., MARTI, N., RIBES, J., RUANO, M. V., SERRALTA, J. AND FERRER, J., 2020, New frontiers from removal to recycling of nitrogen and phosphorus from wastewater in the circular economy. *Bioresour. Technol.*, **300** : 122673.

SHANMUGAM, P. M. AND VEERAPUTHRAN, R., 2000, Effect of organic manure, biofertilizers, inorganic nitrogen and zinc on growth and yield of rabi rice (*Oryza sativa*). *Madras. Agric. J.*, **88** (7-9) : 514 - 517.

SOLAIMALAI, A., BASKAR, M., RAMESH, P. T. AND RAVISANKAR, N., 2001, Utilization of press mud as soil amendment and organic manure-a review. *Agric. Rev*., **22** : 25 - 32.

SUBBIAH, G. V. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.,* **25** : 258 - 260.

TALASHILKAL, S. C. AND PATIL, M. D., 1979, Efficiency of different combinations of water soluble and water insoluble carriers with and without compost in laterite soil of Konkan. *J. Indian Soc. Soil Sci*., **29** (2) : 194 - 196.

WALKLEY, A. J. AND BLACK, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*., **37** : 29 - 38.

YOGANANDA, S. B., REDDY, V. C. AND RAO, G. E., 2010, Effect of biofertlizers, inorganic fertilizers and urban compost on nutrient use efficiency, yield and economics of hybrid rice (*Oryza sativa* L.) production. *Mysore J. Agric. Sci*., **44** (1) : 100 - 105.