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Effect of gypsum enriched poultry manure and graded levels of phosphorus on growth and yield of hybrid maize (*Zea mays* L.)

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Abstract
A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore to study the effect of gypsum enriched poultry manure and graded levels of phosphorus on productivity and profitability of hybrid maize. Enriching poultry manure with gypsum has been found to reduce the ammonia volatilization as well as obnoxious odour and results in manure with better physical and chemical properties. However there is a need to study the effect of gypsum enriched poultry manure on crop growth and productivity. Hence the field experiment was carried out to find out the effect of gypsum enriched poultry manure on growth and yield of maize. The experimental soil was low in organic carbon, high in available nitrogen and medium in available phosphorus and potassium. Twenty treatment combinations involving two factors were replicated thrice in completely randomized block design. The results of the experiment revealed that enriched poultry manure and graded phosphorus levels had a significant influence on the growth and yield of maize. Application of gypsum enriched poultry manure @ 2 t ha^{-1} and phosphorus @ 100 kg P_2O_5 ha^{-1} showed a significant increase in growth and yield parameters like plant height, dry matter production, cob length, cob girth, number of grains per row and individual cob weight. Statistically significant grain yield and stover yield of maize was observed due to the treatments. Hence enriching poultry manure with gypsum is an effective way and eco friendly technique which improves the soil health and increase the crop growth and productivity while reducing the ammonia volatilization from poultry manure.

Keywords: Enriched poultry manure, gypsum, phosphorus, maize

1. Introduction
Application of organic manures to agricultural land is a long term practice followed by farmers which results in sustaining the crop production and maintaining the soil health. Meanwhile due to development of inorganic fertilizers along with high fertilizer responsive varieties lead to decrease in comparative usage of organic manures. However due to recent emerging concerns about prolonged use of inorganic fertilizers alone without addition of organic manures have made the farmers to adopt an integrated system of nutrient management involving both organic and inorganic fertilizers. Among the organic manures, poultry manure is considered to be an excellent nutrient source which is capable of supplying all the essential nutrients to sustain the crop production as well as enhance the soil physical, chemical and biological properties (chan *et al*., 2008) [6]. Regardless of its high nutrient content, depletion of fertilizer value of poultry manure due to higher rate of ammonia volatilization accompanied with odour generation is a major drawback in poultry manure utilization (Nahm, 2005) [12]. Chemical amendments such as addition of gypsum ($CaSO_4$) during composting of poultry manure have been found to reduce the ammonia volatilization and regulate the odour formation with physical properties more suitable for handling (Chen *et al*., 2010) [7]. However it is necessary to study the effect of gypsum enriched compost on plant growth and development and to find the feasibility of enriching manure with gypsum in terms of production and productivity. Among the major plant nutrients, phosphorus is the second important element limiting the plant growth and development. Adequate levels of phosphorus result in better root development and improve the quality of vegetative and reproductive growth (Ahmad *et al*., 2019) [1] However availability of phosphorus is a major problem in many soil types (Ali *et al*., 2012) [2]. Several studies have reported that combining poultry manure and inorganic fertilizers has a potential to increase the phosphorus availability (Garg *et al*., 2008) [9]. Maize is a versatile emerging cereal crop due to its wider adaptability and utilization in various sectors and being a C_4 plant with high productivity potential combined with comparatively higher nutrient demand, needs to be

supplied with a large quantity of nutrients (Prasad *et al*., 2018) [14]. By considering the above facts the research was undertaken with maize as the test crop.

2. Materials and Methods

The field experiment to investigate the effect of gypsum-enriched poultry manure and graded levels of phosphorus on the productivity of hybrid maize was carried out at the Eastern Block Farm of Tamil Nadu Agricultural University, Coimbatore, during summer, 2021. The experimental site was geographically located at 11˚ 1'6" N latitude and 76˚ 58'21"E longitude at an altitude of 426.7 metres above mean sea level. The experimental soil was sandy clay loam in texture with a slightly alkaline pH and an EC of 0.32 dsm^{-1}. The nutrient status available nitrogen (197 kg ha^{-1}) with medium phosphorus (17 kg ha^{-1}) and high potassium availability (514 kg ha^{-1}). The experiment was laid out in a 5 x 4 factorial randomized block design with three replications with a plot size of 7x3 m. Factor I consisted of control without poultry manure application (M_1), composted poultry manure @ 2 t ha^{-1} (M_2), different levels of gypsum-enriched poultry manure applied at 1 (M_5), 1.5 (M_2)and 2.0 t (M_3) ha^{-1} while factor II consisted of graded phosphorus levels at 50 (P_2), 75 (P_3), and 100 kg P_2O_5 ha^{-1} (P_4) and control (without phosphorus P_1). Gypsum enriched poultry manure was prepared by mixing the fine ground dried poultry manure with gypsum at a rate of 10 per cent on a W/W basis. Poultry manure was collected from the poultry shed at the Department of Veterinary and Animal Science, TNAU, Coimbatore. The manure obtained was shade dried and ground into smaller particles for uniform mixing with gypsum. Frequent turning was done to ensure uniform drying. The enriched manure was incubated for 20 days in airtight polythene bags. The gypsum-enriched poultry manure and untreated poultry manure were analyzed for N, P and K content. The agronomic practices for the crop were carried out uniformly in all the treatment plots throughout the crop season as per the crop production guide 2020. Data on growth and yield parameters were collected from five plants that were tagged randomly in the plot. Soil samples were collected from each treatment plot for post harvest nutrient analysis. All the data were analyzed using AGRESS statistical package and the critical difference for treatments are worked out at 5 per cent probability level.

3. Results and Discussion

3.1 Growth attributes

Perusal of the data revealed that growth parameters of maize were significantly influenced by the treatment factors. The growth attributes such as plant height, LAI, dry matter production were highest under application of gypsum enriched poultry manure @ 2 t ha^{-1} (M_3) and the phosphorus dose of 100 Kg P_2O_5 ha^{-1} (P_4) at 30, 60 DAS and at harvest. Significant enhancement in growth attributes under different rates of gypsum enriched poultry manure might be due to the increased availability of calcium with other nutrients due to application of calcium enhanced compost that leads to better crop growth and productivity in the current study which is also in line with findings of Niamat *et al*. (2019) [13]. The effect of increased P levels on plant height is most likely related to improved root growth and nutrient uptake. Organic amendments along with gypsum have been found to improve the growth and productivity of crops such as rice, wheat, sugarcane, cotton, and tomatoes (Ghafoor *et al.*, 2001 and Tejada *et al.*, 2006) [10, 17]. Effect of higher levels of phosphorus on leaf expansion and leaf growth might be the result of increased LAI. Similar findings were reported by Araei and Mojaddam (2014) [4]. Higher levels of phosphorus application results in more phosphorus availability to plants which results in more assimilate formation and partitioning which subsequently results in increased dry matter production. The results obtained were also in line with findings of Amanullah *et al*. (2010) [3]. Significant variation in dry matter production might be due to the variation in overall growth and development and it is also evident from the observations of various growth parameters like plant height, LAI and dry matter production.

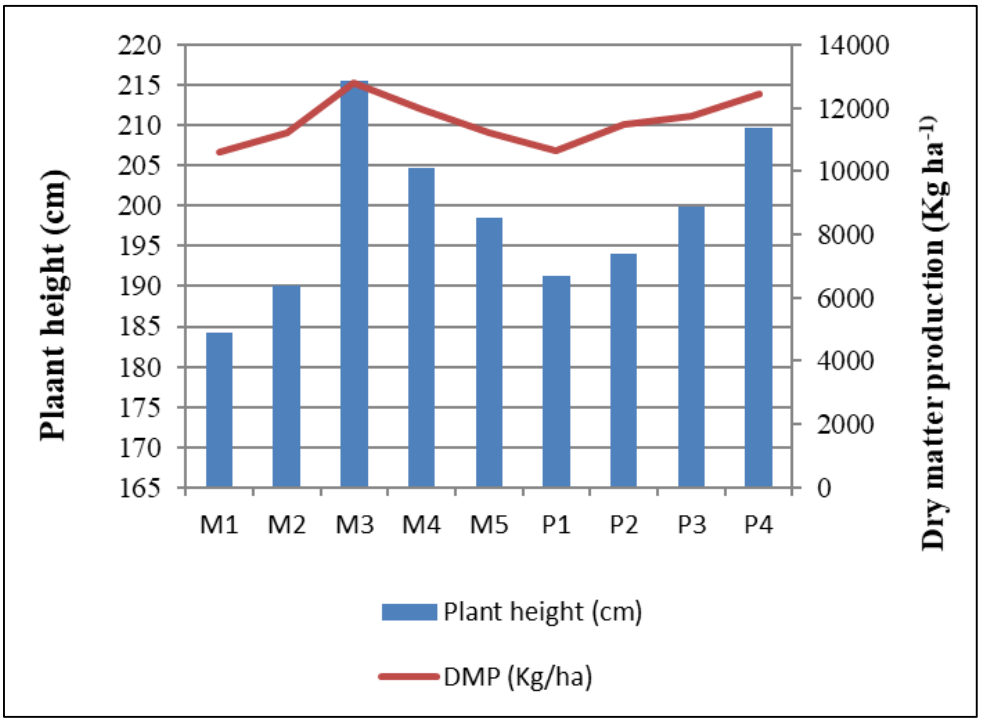

Fig 1: Effect of gypsum enrichced poultry manure and graded levels of phosphorus on plant height (cm) and dry matter production (Kg ha^{-1}) at harvest

Table 1: Effect of gypsum enriched poultry manure and graded levels of phosphorus on growth parameters of maize at 30, 60 DAS and at harvest stage

Treatments	Plant height (cm)			LAI			DMP (kg ha^{-1})		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Control	69.81	149.90	193.41	1.78	2.73	3.73	1529	6314	10630
Composted poultry manure 2 t ha^{-1}	79.92	159.53	195.16	1.83	3.05	4.10	1621	7358	11216
Gyp.enriched PM @ 2 t ha^{-1}	93.30	179.42	198.36	1.90	3.31	4.46	1843	8543	12813
Gyp.enriched PM @ 1.5 t ha^{-1}	87.51	171.39	207.13	1.77	3.25	4.36	1722	8094	11989
Gyp.enriched PM @ 1 t ha^{-1}	84.24	171.50	198.52	1.92	3.21	4.31	1627	7607	11217
SE (d)	2.04	4.41	4.63	0.10	0.06	0.06	43.68	218.27	254.47
CD	4.13	8.94	9.39	NS	0.14	0.13	88.43	441.87	515.16
Phosphorus levels									
Control	79.50	159.96	191.34	1.85	2.91	4.00	1595	7187	10641
50 kg P_2O_5 ha^{-1}	81.55	163.40	194.04	1.81	3.09	4.15	1598	7344	11470
75 kg P_2O_5 ha^{-1}	83.35	166.93	199.94	1.82	3.18	4.26	1683	7718	11738
100 kg P_2O_5 ha^{-1}	87.41	175.11	209.77	1.87	3.25	4.36	1798	8084	12442
SE (d)	1.82	3.95	4.14	0.09	0.06	0.06	39.07	195.23	508.95
CD	3.69	7.99	8.39	NS	0.12	0.12	79.10	395.22	NS

Gyp. enriched PM – Gypsum enriched poultry manure

3.2 Root parameters

The root parameters were significantly influenced by the treatment combinations. In the same way application of enriched manure at 2 t ha^{-1} increased the root length, root volume and root dry matter up to 42.46 cm, 117.80 cc, 1068.66 kg ha^{-1} respectively. Among the phosphorus levels 100 kg P_2O_5 ha^{-1} resulted in maximum root length (42.30 cm), root volume (110.93 cc) and root dry weight (1023.75 kg ha^{-1}) at harvest stage. In the present study no significant interaction was observed between the two treatment factors. The results were in conformity with results obtained by Farina *et al.* (2000) [8].

Table 2: Effect of gypsum enriched poultry manure and graded levels of phosphorus on root parameters of maize at 30, 60 DAS and at harvest stage

Treatments	Root length (cm)			Root volume(cc)			Root dry mass(Kg ha^{-1})		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Control	16.94	26.20	32.13	78.42	91.13	93.95	308	681	899
Composted poultry manure 2 t ha^{-1}	21.02	29.31	36.88	93.34	100.11	100.95	373	752	955
Gyp.enriched PM @ 2 t ha^{-1}	24.24	38.19	42.46	101.13	110.18	117.80	460	892	1069
Gyp.enriched PM @ 1.5 t ha^{-1}	22.63	33.48	39.99	95.85	104.87	109.82	418	840	998
Gyp.enriched PM @ 1 t ha^{-1}	21.38	34.88	39.91	93.19	101.04	101.99	400	842	956
SE (d)	0.59	0.91	1.19	2.34	2.76	1.96	23	24	29
CD	1.21	1.84	2.42	4.74	5.58	3.98	46	48	57
Phosphorus levels									
Control	20.05	29.04	35.06	86.57	95.40	99.35	359	791	949
50 kg P_2O_5 ha^{-1}	20.11	31.12	36.92	89.11	97.70	103.03	383	757	955
75 kg P_2O_5 ha^{-1}	21.51	33.43	38.82	94.40	103.56	106.29	394	804	973
100 kg P_2O_5 ha^{-1}	23.28	36.05	42.30	99.46	109.20	110.93	431	854	1024
SE (d)	0.59	0.81	1.07	2.09	2.46	1.75	21	21	26
CD	1.21	1.65	2.46	4.24	4.99	3.56	42	43	53

Gyp. enriched PM – Gypsum enriched poultry manure

3.3 Yield attributes

Significantly higher values of cob length, cob girth, number of grains per cob and individual cob weight were recorded under application of gypsum enriched poultry manure @ 2 t ha^{-1} which is followed by 1.5 t ha^{-1} of gypsum enriched poultry manure. Since P promotes strong root growth, which has a direct impact on total plant performance, P regimes of 100 kg ha^{-1} produced more number of grains per cob and higher individual cob weight. Similar findings were also reported by Sadiq *et al.* (2017) [15].

3.4 Yield

The data regarding the yield of maize were significantly influenced by the gypsum enriched poultry manure and graded levels of phosphorus. The grain yield and stover yield were highest under application of 2 t ha^{-1} of gypsum enriched poultry manure and 100 Kg P_2O_5 ha^{-1}. The variation in grain and stover yield might be due to higher values of all the yield attributing characters. Gypsum along with organic manure results in soil conditioning effect which improves the soil physical properties which results in improved supply of Ca and S which improves the overall performance of crop growth and productivity of maize. Similar findings were also reported by Sawyer *et al.* (2011) [16] and Changati *et al.* (2019) [5]. Increased root growth, which allows plants to explore more soil nutrients and moisture, is directly linked to a good and optimal supply of phosphorus which ultimately leads to increased crop yield. These findings are in line with those achieved by Masood *et al.* (2011) [11] and Sadiq *et al.* (2017) [15].

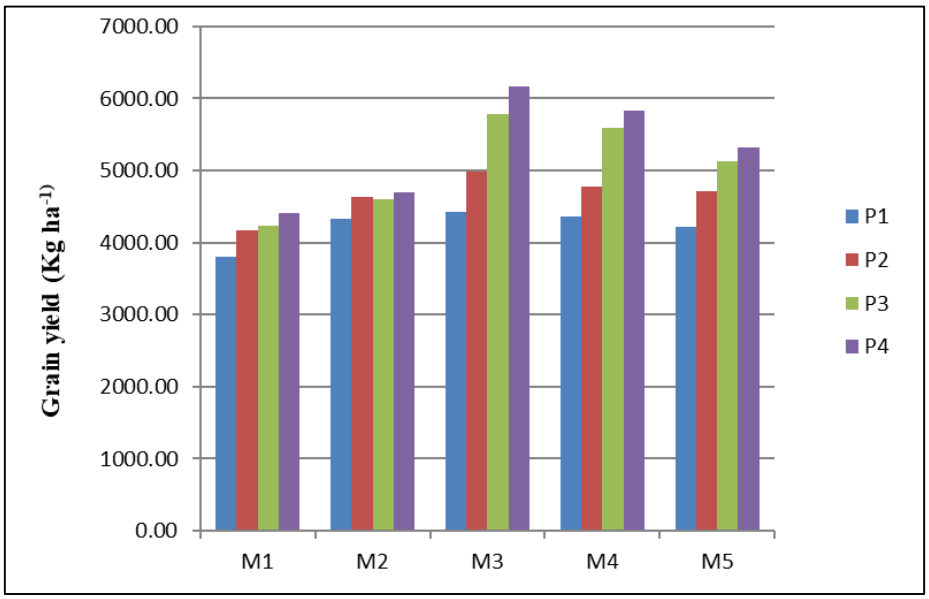

Fig 2: Effect of gypsum enriched poultry manure and graded levels of phosphorus on grain yield of maize

Table 3: Effect of gypsum enriched poultry manure and graded levels of phosphorus on yield and yield attributes of maize hybrid COH(M) 8

Treatments	Cob length (cm)	Cob girth (cm)	No. of grain rows/cob	No. of grains/row	Individual cob weight (g)	Total grains per cob	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})
Control	13.83	12.56	13.45	21.33	170.19	303.85	4150	10998
Composted poultry manure 2 t ha^{-1}	15.37	13.74	13.91	26.60	183.85	347.55	4566	11580
Gyp. enriched PM @ 2 t ha^{-1}	17.90	15.21	14.33	32.94	220	441.50	5339	12774
Gyp. enriched PM @ 1.5 t ha^{-1}	16.90	14.23	14.37	29.37	201.82	418.45	5137	12124
Gyp. enriched PM @ 1 t ha^{-1}	16.10	14.09	14.25	27.16	187.90	391.06	4843	12212
SE (d)	0.38	0.43	0.40	0.80	5.34	16.03	116	283
CD	0.78	0.87	NS	1.63	10.82	32.44	235	572
Phosphorus								
Control	14.95	13.08	13.83	24.78	181.95	343.19	4226	11374
50 kg P_2O_5 ha^{-1}	15.64	13.87	13.93	27.24	184.54	367.73	4653	11822
75 kg P_2O_5 ha^{-1}	16.30	14.05	14.16	28.20	197.33	389.16	5067	12091
100 kg P_2O_5 ha^{-1}	17.19	14.86	14.33	29.70	207.18	421.84	5283	12523
SE (d)	0.34	0.38	0.36	0.72	4.78	14.33	104	253
CD	0.70	0.78	NS	1.45	9.67	29.01	210	512

Gyp. enriched PM – Gypsum enriched poultry manure

4. Summary and Conclusion

Results of the study conducted clearly showed that application of gypsum enriched poultry manure had a significant influence on the growth and yield attributes of maize as compared to poultry manure without enrichment. As regards to phosphorus levels, significant increase in growth and yield attributes were noticed with increase in phosphorus levels. From the study it is concluded that application of gypsum enriched poultry manure at 2 t ha^{-1} and phosphorus @ 100 kg P_2O_5 ha^{-1} resulted in higher values of growth and yield attributes. It is summarized that application of Ca enriched manure significantly enhanced the growth, yield, and physiological characters in maize as compared to the control and individual application of compost. Hence the technique of enriching poultry manure with gypsum can be considered as a promising approach with positive influence on growth and yield characters of maize.

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