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Comparative evaluation of ammonia volatilization between deep placed and surface applied fertilizers in soil

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Abstract
Ammonia volatilization is a potential loss of nitrogen to the environment and it reduces the nitrogen use efficiency. A soil incubation experiment was conducted to compare the ammonia volatilization of surface applied fertilizers and deep placed fertilizers under different soil medium (moist soil and submerged soil) for the period 48 days. For deep placement, the encapsulated fertilizer pellet and for surface application, the same quantity of fertilizer as that of fertilizer pellet was applied on the surface. Ammonia volatilization (mg) and Cumulative ammonia volatilized (%) were higher in the moist soil which is not flooded than flooded soil medium irrespective to the method of application. Surface applied fertilizers were led to more ammonia losses through volatilization than deep placed fertilizers. Under non-flooded condition of soil, the cumulative ammonia volatilized was higher in surface applied fertilizer (6.46%) than from deep placed fertilizer pellet (5.42%). Similarly under submergence, the ammonia volatilization is reduced and the cumulative ammonia volatilized was found high in surface applied fertilizers (6.1%) than deep placed fertilizer pellet (0.14%). The results revealed that the deep placement of fertilizer pellet is significantly beneficial to minimize ammonia loss to the environment than surface application that to very effective under flooded soils.

Keywords: Ammonia volatilization, Incubation, Encapsulated fertilizer pellet, Surface application, Deep placement

Introduction
Nitrogen is the most important element required for plant growth and development. Variation in nitrogen availability can affect plant development and grain production. Among the nitrogen sources, urea is the highest consumed fertilizer worldwide and India is the 2nd biggest consumer of urea. The consumption of nitrogenous fertilizers is showing increasing trend every year. The consumption of NPK ratio was increased from 4.6:2.0:1 during 2008-09 to 8.2:3.2:1 during 2012-13 (Indian Fertilizer Scenario, 2013) [9]. With increasing demand for food production, we need to enhance the Fertilizer Use Efficiency by effective utilization of fertilizer and also for cost effectiveness. All applied nutrients are not utilized by the crops for their production. Among the nitrogen fertilizer sources, Urea has been reported to have lower fertiliser use efficiency (FUE) relative to ammonium and nitrate-based fertilisers (Zaman *et al.* 2008) [16]. Through hydrolysis process, urea is converts to ammonia-N and it may be lost from soil as a gas by two major mechanisms ammonia volatilization and denitrification. Galloway *et al.* (2002) [7] reported that even in well-managed cereal crops, about 40 to 60% N is lost. Frame *et al.* (2012) [6] reported that N loss through volatilization may be as great as 70% of the applied fertilizer. While >40% of the applied N is reported to be lost as NH_3 under certain environmental and edaphic conditions (Singh *et al.*, 2013) [15], an average of 10–14% of N is lost via volatilization from synthetic fertilizers (Bouwman *et al.*, 2002) [3]. Ultimately the nitrogen losses to the environment will result in low N use efficiency. The most important task for the future is to improve nutrient use efficiency or more precisely nitrogen use efficiency (Grant, 2005) [8]. Ammonia (NH_3) volatilization should be mitigated through appropriate fertilizer products or else improved management practices. To increase use efficiency of nutrients deep placement of fertilizers is one of the oppurtunities. Bautista *et al.* (2001) [1] concluded that placement of any N material with simultaneous soil cover was effective in minimizing floodwater ammonium-N losses and ammonia volatilization. Mohanty *et al.* (1999) [11] indicated that nitrogen deep placement resulted in a dramatic reduction in flood-water NH_4^+–N concentration and consequently decreases in NH_3 volatilization.

With the consideration of deep placement of fertilizer pellet as good management practice to ammonia loss, an incubation study was carried out to compare the ammonia volatilization of deep placed fertilizer pellet with surface applied fertilizers under moist soil and submerged soil medium.

Materials and Methods

Soils of upland was used for this incubation study. The collected soils were processed through 2 mm sieve and filled in the plastic container having lid and the soil properties are presented in Table. 1. The processed soils were filled in set of plastic containers having 15 cm bottom diameter, 17 cm top diameter and 23 cm height (Fig. 1). The top of container had screw threads for capping with lid tightly without air leakage. In each container 1000 g soil was added. Polycoated fertilizer pellet placement (T1), Polycoated fertilizer pellet with manure pellet placement (T2) and surface application of fertilizers application (T3) are the different treatments compared. With the deep placement of fertilizer pellet, manure pell*et al*so added (Nutripellet pack) to assure the effect of INM. For surface broadcast treatment calculated amount of urea, diammonium phosphate and muriate of potash were weighed to contain 630 mg N and applied on surface of the container. Then encapsulated fertilizer pellet together with manure pellet as per treatment was placed at the centre and the remaining 1000 g soil was filled uniformly around the pack and also covering the top of the pack. For the surface broadcast application initially 1800 g soil was placed inside the beaker. Then fertilizers were applied uniformly on surface and covered with remaining 200 g soil. After imposing treatments, 75 per cent WHC and 5 cm of standing water was maintained for moist and submerged soils respectively. In each container, 100 ml glass beaker was placed. Inside the beaker 20 ml of 2 per cent boric acid solution with double indicator (Bromocresol green and methyl red) was added to trap the ammonia volatilized. At regular interval, the beaker having boric acid were replaced with the boric acid containing beaker and titrated against 0.1 N H_2SO_4. The top of container was closed tightly with screw lid. The whole set up was kept undisturbed inside the laboratory under room temperature, until measurements. Measurement of Ammonia volatilization was done at 4 days interval for 48 days after incubation. From the evolved ammonia, ammonia volatilized (mg) and cumulative ammonia volatilized (%) were calculated. Data derived were subjected to ANOVA and means were separated by critical difference at 5% level of significance using AGRES statistical package.

Ammonia volatilization

AV(mg) = TV (DY) X 0.0014 X 1000

Where, TV (DY) – Titre value at measurement on days after incubation

Cumulative ammonia volatilized (%)

$$CAV\ (\%) = \frac{\text{Ammonia volatilized for given period (g)}}{\text{Fertilizer N applied (g)}} \times 100$$

Fertilizer pellet pack making

Fertilizer pellets were prepared with the fertilizer required for crop based on per plant requirement as per recommended dose of fertilizers. In the feed tray of pelleting machine the fertilizer mixture (Urea, DAP, Muriate of Potash) prepared as per treatment was placed. Then by the reciprocating action of the piston fertilizer mixture was compacted and taken out as fertilizer pellet measuring about 30 mm length. Each fertilizer pellet was placed in a small pouch made of polyester coated paper and the mouth was sealed with the sealing machine. The pelleted fertilizers were encapsulated with slow release poly material.

Results and Discussion

Measurement of ammonia volatilization was done up to 48 days after incubation at 4 days intervals. The amount of ammonia volatilized from the surface applied fertilizers (Urea, DAP and MOP) and from Nutripellet Pack (Fertilizer pellet + Manure pellet) in moist upland soil and submerged lowland soil were estimated. The effect on ammonia volatilization was recorded and expressed as amount of ammonia volatilized (mg) and cumulative ammonia volatilized (%).

Amount of ammonia volatilized (mg)

High ammonia volatilization was noted for surface broadcast, which was very large (21.4 mg) on 4th day and steeply decreased to negligible value on 48th day. The ammonia volatilization of surface applied fertilizer were increasing in initial day after reaching specific period (32nd day), the amount ammonia released are negligible. NH_3 fluxes peaked within 3–5 days after each nitrogen fertilization, which may be related to enzymatic hydrolysis of applied nitrogen fertilizers (Zhang *et al.*, 2011; Shang *et al.*, 2014) [17, 14]. From fertilizer pellet pack initially no ammonia volatilization was found which increased steadily and attained high amount of ammonia volatilized (61 mg) increasing with days of incubation. Likewise, placement of fertilizer pellet with manure pellet (Nutripellet pack) recorded increased amount of ammonia volatilization with increase in incubation period. On 4th day low amount of ammonia volatilized was recorded (0.14 mg) which reached the peak amount of ammonia volatilized on 44th day (1.8 mg) (Fig. 2). The highest ammonia volatilization was registered significantly in placement of fertilizer pellet pack followed by surface application of fertilizers and Nutripellet pack. This might be due to the interaction effect of soil particles and nitrogen source of fertilizers. When the interaction increases the ammonium ion concentration increases in the soil solution which might increase the chance of ammonia volatilization (Cao and Yin, 2015) [5]. Established polycoat paper used for encapsulation was permeable to electrolytes and nutrients in solution. While measuring ammonia volatilization, it was found that polycoat paper would also permit the transfer of ammonia from inside to outside of the pack. Similarly, ammonia volatilization from fertilizer pellet placed under submerged condition of soil with 5 cm water depth was measured (Fig.3). Surface applied fertilizer recorded the highest ammonia volatilization on 4 day (2.24 mg) itself and then increased and reached the highest ammonia volatilization on 28th day of incubation (4.20 mg) and later showed declining trend. Polymer coated urea might minimize the N loss under submergence than surface application (Noellsch *et al.*, 2009) [12]. Sub-surface banding or deep placement of urea reduced NH_3 volatilization when compared to surface broadcast of urea on calcareous or well-buffered soils (Cai *et al.*, 2002) [4]. The surface application of fertilizers liberated the enormous amount ammonia uncontrollably at all period of measurements when compared to placement of fertilizer pellets. Beres *et al.* (2012) [2] called polymer coated urea as environmentally smart nitrogen (ESN) source that provides controlled release, allowing highest safe rates of urea fertilizer. Possibly the fast dissolution and release of diammonium phosphate to outer solution would have directly induced ammonia volatilization under surface application of fertilizers (Kalaiselvi *et al.*, 2017) [10]. Invariably placement of fertilizer pellet registered the least ammonia volatilization throughout the period under submerged condition at least 10 times. Fertilizer pellet pack with or without manure pellet were equally influenced ammonia volatilization. Ammonia volatilization rate ranged from 0.1 to 20.4 mg day^{-1} in moist soil and ranged from 0 to 1.9 mg day^{-1} in submerged soil.

Cumulative ammonia volatilization (%)

Among the incubation periods, cumulative ammonia volatilization increased with increase in days of incubation. Cumulative ammonia volatilization in moist soil ranged from 0.85 to 3.55 per cent irrespective of the treatments. Surface application of fertilizers recorded the highest cumulative ammonia volatilization (6.46%) followed by placement of fertilizer pellet pack alone (5.4%). Under submerged condition (Table. 2) of the soil, the highest cumulative ammonia volatilization was registered in surface application of fertilizers which was followed by placement of fertilizer pellet with or without manure pellet. While comparing the incubated soils, the highest cumulative ammonia volatilization was registered in moist soil (upland soil condition) followed by submerged soil. As stated by Sanz *et al.*, 2011 [13], the ammonia loss to the environment is exacerbated by delaying the irrigation to the soil.

It can be concluded that Ammonia volatilization from surface application of fertilizers immediately occurred irrespective of the soil moisture particularly much associated with surface applied fertilizers. Whatever be the media of soil around the encapsulated pellet containing NPK, the peak amount of ammonia volatilization occurred between 34 and 38 days, and loss accounted for was 5.4 per cent and 3.3 per cent in surface application of fertilizer during the period of 48 days in moist upland and submerged lowland soils respectively. Substantial reduction in ammonia volatilization was estimated in moist clay loam and submerged clay loam where high clay fractions were present. The use of non-urea based fertilizers, reduced fertilizer application rate, deep placement of fertilizers, irrigation, urease inhibitors and controlled release fertilizers are effective in reducing NH_3 volatilization.

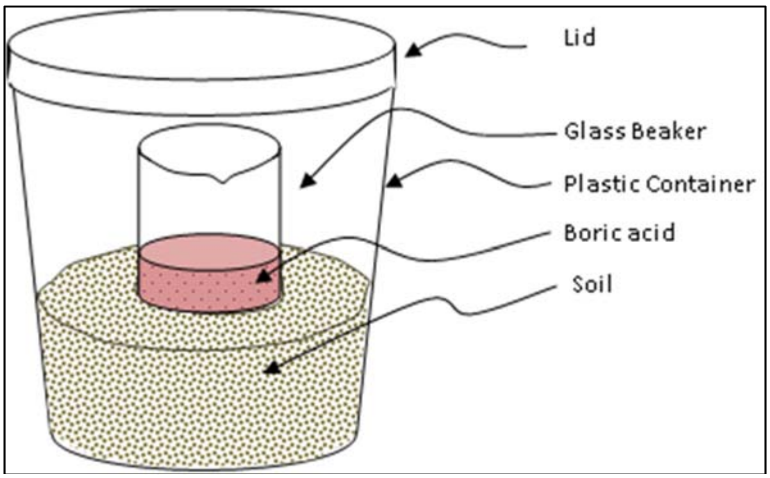

Fig 1: Laboratory Measurement of Ammonia Volatilization

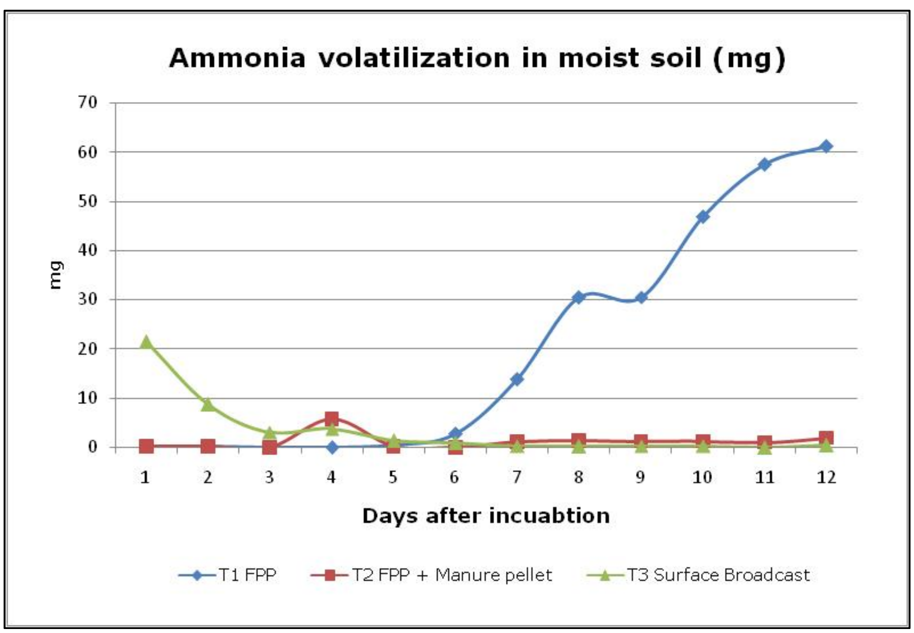

Fig 2: Ammonia volatilization in moist soil (mg)

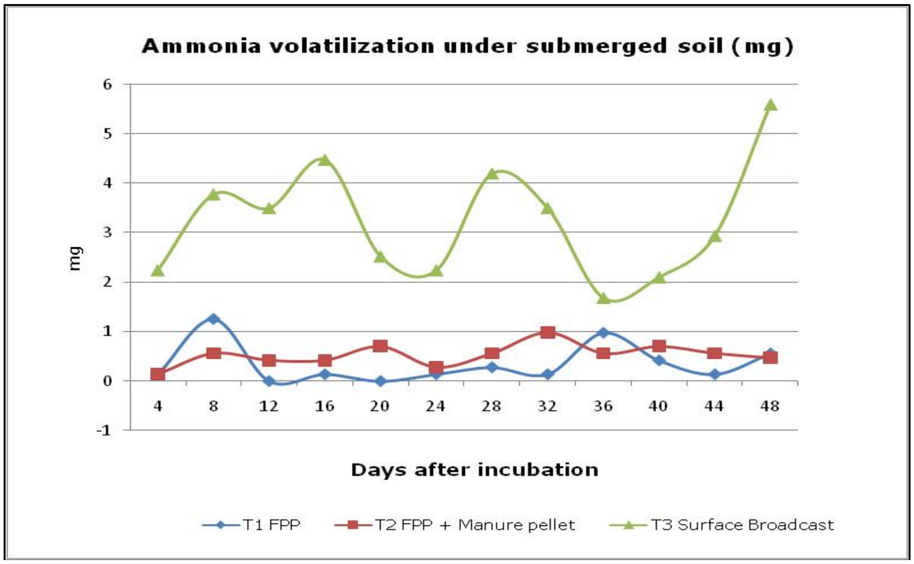

Fig 3: Ammonia volatilization in submerged soil (mg)

Table 1: Properties of soil used for incubation study

S. No.	Properties			Value
	A. Physical properties			
1.	Coarse sand	(per cent)	:	16.6
2.	Fine sand	(per cent)	:	26.4
3.	Silt	(per cent)	:	20.7
4.	Clay	(per cent)	:	35.3
5.	Texture		:	Clay loam
6.	Bulk density	(Mg m^{-3})	:	1.30
	B. Physico chemical properties			
1.	pH		:	8.63
2.	EC	(dS m^{-1})	:	0.20
3.	CEC	(cmol (p^+) kg^{-1})	:	22.7
	C. Chemical properties			
1.	Total nitrogen	(per cent)	:	0.15
2.	Total phosphorus	(per cent)	:	0.11
3.	Total potassium	(per cent)	:	0.54
4.	$KMnO_4$ –N	(kg ha^{-1})	:	245
5.	Organic carbon	(g kg^{-1})	:	5.4
6.	Olsen-P	(kg ha^{-1})	:	11.88
7.	NH_4OAc –K	(kg ha^{-1})	:	615
8.	DTPA- Fe	(mg kg^{-1})	:	11.64
9.	DTPA- Mn	(mg kg^{-1})	:	8.84
10.	DTPA- Zn	(mg kg^{-1})	:	1.51
11.	DTPA- Cu	(mg kg^{-1})	:	3.19

Table 2: Effect of Fertilizer pellet pack with additives on cumulative ammonia volatilization (%) in moist soil and submerged soil

Treatments		Days of sampling												Mean
		4	8	12	16	20	24	28	32	36	40	44	48	
Moist soil (Unflooded)														
T_1	FPP	0.00	0.01	0.01	0.01	0.02	0.08	0.39	1.07	1.75	2.79	4.07	5.42	1.30
T_2	FPP + Manure pellet	0.00	0.01	0.01	0.13	0.14	0.14	0.16	0.19	0.22	0.25	0.27	0.31	0.15
T_3	Surface Broadcast	3.40	4.78	5.27	5.87	6.09	6.22	6.27	6.29	6.33	6.38	6.38	6.46	5.81
	Mean	0.85	1.20	1.32	1.51	1.58	1.66	1.86	2.11	2.44	2.76	3.14	3.55	2.00
		T				P				T X P				
SEd		0.36				0.56				1.26				
CD (P=0.05)		0.81				1.25				2.80				
Submerged soil (Flooded)														
T_1	FPP	0.00	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.07	0.08	0.08	0.09	0.05
T_2	FPP + Manure pellet	0.00	0.02	0.02	0.03	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.14	0.07
T_3	Surface Broadcast	0.36	0.96	1.51	2.22	2.62	2.98	3.64	4.20	4.47	4.80	5.27	6.16	3.26
	Mean	0.09	0.25	0.39	0.57	0.68	0.77	0.94	1.09	1.16	1.26	1.38	1.61	0.85
		T				P				T X P				
SEd		0.08				0.12				0.30				
CD (P=0.05)		0.18				0.28				0.62				

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