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DEEP PLACEMENT FERTILIZER APPLICATORS FOR WET PADDIES

by

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SUMMARY:

Fertilizer use efficiencies in wetland paddy production are about half that of dryland crops. Deep placement of fertilizer has been recognized as a method to increase fertilizer use efficiency. Inspite of numerous efforts worldwide, it had not been possible to place fertilizer deep in flooded paddies because of the problems of rapid transfer of N to floodwater during placement. This paper reports the development of three new applicators which can successfully deep place fertilizer in flooded paddies and offer possibilities for substantial yield increases in Asian paddy production.

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DEEP PLACEMENT FERTILIZER APPLICATORS FOR WET PADDIES

By

*Amir U. Khan**

INTRODUCTION

Paddy farmers in Asia have not been able to make full use of fertilizer to boost their yields due to poor fertilizer use efficiencies. As early as 1941, Shioiri in Japan explained the mechanics of loss of surface applied ammonia in flooded soils and recommended the deep placement of ammonium fertilizers. Many studies at IRRI and other institutions have consistently demonstrated that fertilizer use efficiency in wetland rice production could be almost doubled by placing fertilizer in the reduced soil layer at depths ranging from 5 to 15 cm. A lack of suitable deep placement applicators however, has not permitted the transfer of these findings to the farm level.

Prilled urea is the most popular fertilizer material used for rice production in Asia. Over the last decade an unusually large number of deep placement applicators have been developed (Kiamco, 1982 & Liu Chung-chu, 1982) for prilled urea in Japan, China and at IRRI. Field performance of these machines however have been rather inconsistent. This has led to the belief that prilled urea is not a suitable fertilizer material for deep placement and consequently briquettes and urea supergranules** have been experimentally developed.

The Institute is fully aware of the immense benefits that could accrue to rice farmers in Asia through deep placement of fertilizer and is placing a high priority on the development of such fertilizer applicators. In September 1982, the author was assigned to IRRI to concentrate on the development of deep placement applicators. A special engineering team*** was organized by the author in the Agricultural Engineering Department to work on this critical problem.

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***Urea Briquettes & Urea Supergranules are essentially large size granules of 1 gram weight that were developed to facilitate deep placement in flooded soils.*

****The engineers who have been associated from time to time with this special task force are: Larry Kiamco, Val Tiangco, Gil Espiritu, Iñigo Camacho, Lito Diestro, Research Assistants, & Lito Bautista, Felipe Santos & Zahid Mahmood, Research Scholars of the Agricultural Engineering Department, IRRI, Los Baños, Laguna, Philippines.*

As an initial step, a review of the deep placement applicator development worldwide were undertaken to gain a better understanding of the deep placement problem. This led to the development of a set of criteria (Table 3) for technical and commercial acceptability of applicators (Khan, September 1982). In order to gain a better understanding of the deep placement phenomenon, a series of laboratory experiments were conducted, which led to the significant findings that under flooded conditions, placement of fertilizer in open furrows followed by furrow closing results in a large transfer of fertilizer to floodwater. The technical criteria for applicators were subsequently revised to reflect the new findings. Efforts were then made to separately optimize the designs of the three major components of applicators in the laboratory, i.e., the fertilizer metering, conveying and furrow closing mechanisms.

Twenty new deep placement applicator concepts were then proposed (Khan, November 1982) out of which six were selected for intensive design and development efforts. This led to the eventual development of three new applicators. These applicators, two for prilled urea and one for USG were designed for minimum N transfer to floodwater. A brief discussion of the research study on N transfer to floodwater, which served as the basic foundation for the successful development of deep placement applicators, is included in this paper.

MECHANICS OF N TRANSFER TO FLOODWATER

Fertilizer use efficiencies in upland farming (unflooded conditions) have been reported to be 50 to 60% (Craswell & Velk, 1979) when those obtained under wetland farming conditions are generally 30 to 50% (Prasad & De Datta, 1979). The reasons of this wide difference in fertilizer use efficiencies have not been well understood. Experiments conducted in Pakistan (Ross, 1980) indicate a 60% recovery of applied nitrogen by rice crop when fertilizer was incorporated in dry condition and followed by flooding. More recently, Bhatti et al (1983) report that fertilizer incorporated in dry soil and followed by flooding increases paddy yields by 1 to 2 tons/ha over conventional broadcasting of fertilizer in flooded soils. One can conclude from the results of these two studies that flooding, after the fertilizer has been incorporated, is not the cause for reducing fertilizer use efficiencies in wetland farming. Since fertilizer use efficiencies under upland farming (unflooded) conditions are quite high, it was hypothesized that the low fertilizer use efficiencies in wetland farming had something to do with the presence of water during the time the fertilizer was being applied. It was suspected that some fertilizer was being transferred to floodwater during application. Since ammonia volatilization losses are related to floodwater N levels, minimizing floodwater N level seemed a logical approach for reducing fertilizer losses.

In flooded soils, there are four possible ways that fertilizer could be transferred to floodwater during or immediately after placement (Fig. 1a): 1) By dissolution while fertilizer transits through floodwater to the furrow bottom. 2) By upward movement of fertilizer granules or solution due to displacement effect of the furrow closing operation. 3) By convectional movement of fertilizer solution through poorly sealed furrow walls, and 4) By diffusion through water untrapped in puddled soils or between poorly closed furrows. A set of hypothetical curves indicating possible channels of fertilizer transfer to floodwater and the experimental methods which were used to isolate these effects are given in Fig. 1b.

The above considerations led to two laboratory studies in the IRRI Agricultural Engineering Department which permitted the assessment of the different avenues of N transfer to floodwater during deep fertilizer placement. Prilled urea was used in the first study (Khan et al, April 1983) as this material was considered to be most susceptible for N transfer to floodwater due to its small granule size. Similar experiments were later repeated with both prilled urea and urea supergranules (Mahmood et al, 1983). Fig. 1c summarizes the magnitude of N transfer to floodwater during placement when prilled urea is placed in 5 cm deep furrows.

The findings of these two studies confirmed that the applicators developed in the past were not properly depositing fertilizer as most of it was transferred to floodwater during placement. The two major channels of fertilizer transfer to floodwater during deep placement were: a) Dissolution of fertilizer during transit from the water surface to the furrow bottom (43-76%); b) Upward movement of fertilizer granules or solution to the floodwater during furrow closing (up to 29%). If the furrow was properly closed, transfer through the closed furrow walls was generally less than 10%. Transfer due to diffusion through flooded soils was less than 5%.

On the basis of the N transfer studies, it was concluded that the key to improving fertilizer use efficiency in wetland cultivation was to minimize N transfer to floodwater during the fertilizer placement operation. Such a strategy would maximize retention of fertilizer in the soil where it would be less vulnerable to volatilization losses and would be available for plant use. It was thus concluded that minimizing fertilizer-water contact during the three phases of fertilizer application; transit, placement and covering were the most critical considerations in the development of deep placement applicators.

This general stragegy was followed in the development of the following three new applicators (Khan et al, June 1983) at IRRI:

1) Straight auger applicator for prilled urea (Fig. 2).
2) Oscillating plunger applicator for prilled urea (Fig. 3).
3) Press-wedge applicator for urea supergranules (USG) (Fig. 4).

COMPARATIVE PERFORMANCE OF APPLICATORS

During development, most machines must undergo a phase in which machines are repeatedly evaluated and improved. In the past, performance of deep placement applicators were evaluated at IRRI through yield experiments. This required a five to six month cycle, between design improvement and performance evaluation, which seriously delayed the applicator development process. The level of urea and Ammonium N concentration in floodwater, after the fertilizer has been applied, is generally related to volatilization losses. it was felt that floodwater N level* could be used to obtain an approximate idea of the machine placement efficiency. This technique was used for quick preliminary evaluation of applicators which helped to accelerate the applicator development process at IRRI.

Last December, three deep placement applicators were evaluated in Maahas clay plots at IRRI by measuring the amount of N transfer to floodwater. The plots were settled for ten days after puddling. The results of this test, which are summarized below, indicated that the straight auger applicator for prilled urea was performing considerably better than the deep plunger (USG), and rolling presswheel (forestry grade) applicators.

Machine	Fertilizer material	Total N (ppm) in flood water - 24 hours after application	Machine performance rating
Straight auger	Prill	16.47	1
Deep plunger* (intermittent)	USG	34.37	2
Rolling presswheel	Forestry grade	38.63	3

*This machine was developed earlier and had given best performance in tests conducted during 1981-82. However it has some drawbacks which limit its commercial acceptability.

*Subsequent experience tells us that floodwater N level only gives an indication of the amount of N transferred to floodwater during the process of fertilizer application. It fails to give any indication of how the rest of the fertilizer will be available to plants during the rest of the cropping season. Thus the floodwater N level, at placement time, may not necessarily give an indication of fertilizer use efficiencies which is more a function among others of how effectively fertilizer was sealed in the furrow at the time of placement.

During the 1983 dry season, three of the new applicators, the Deep Plunger (USG) and hand placed (USG) methods were evaluated at the IRRI Research Farm in yield trials under a collaborative project between the IRRI Agronomy and Agricultural Engineering departments. The results of these tests were as follows:

PRELIMINARY YIELD TESTS, 1983 DRY SEASON, IRRI AGRONOMY DEPT.

Machine	Fertilizer material	Fertilizer Kg/N ha	Grain yield	Efficiency Kg rough rice / kg N
1) Straight auger 3/4"	Prill	78	5.9	28
2) Auger with transplanter	Prill	82	5.6	23
3) Rolling presswheel	Forestry grade	84	6.0	26
4) Deep plunger (Intermittent)*	USG	84	5.5	21
5) Hand placed	USG	87	5.9	24

*This machine was developed earlier and had given promising performance in tests conducted in 1981-82. This machine, however, has some drawbacks which limit its commercial acceptability.

The performance of the three machines, Nos. 1, 2 & 3, in the above tests compared favorably with hand placement of USG, which had so far been considered to be the most efficient deep placement method at IRRI.

All the five new machines were again tested at the IRRI Research Farm in May 1983 by the Agricultural Engineering Dept. by evaluating the N transfer to floodwater. The results were as follows:

Machine	Fertilizer material	Total N (ppm) in floodwater - 24 hours after application	Machine performance rating	Fertilizer rate kg N/ha
1) Straight auger 3/4" surface closure	Prill	3.3	3	58
2) Straight auger 3/4" with underground closure	Prill	2	1	58
3) Rolling presswheel with underground closure	Forestry grade	11.6	7	58
4) Rollimg presswheel with underground closure	USG	6.7	5	58
5) Inclined nress-wedge	USG	14.8	8	57
6) Oscillating plunger with underground closure	Prill	2.4	2	58
7) Auger 3/4" on transplahter	Prill	8.7	6	58
8) Deep plunger (intermittent)*	USG	6.2	4	58
9) Hand placement	USG	6.7	5	58

*This machine was developed earlier and had given promising performance in tests conducted in 1981-82. However, it has some drawbacks which limits commercial acceptability.

These tests indicate an encouraging performance of all five machines as the N transfer values were less than 25 ppm, a level that was agreed upon by scientists at IRRI to be acceptable. The two prilled urea applicators, the Straight Auger and the Oscillating Plunger, resulted in a lower N transfer to floodwater than hand placement of USG. This was convincing proof that prilled urea could be as effectively deep placed as USG. The performance of the Rolling Presswheel was satisfactory however this machine was dropped from further development as it was felt to be too costly for commercial introduction. The Inclined Press-wedge indicated a relatively high N transfer value and hence the wedge and opener was redesigned with a narrow profile for more effective sealing and reduced pushing force.

The three new machines, the Straight Auger (prill), the Oscillating Plunger (prill) and the modified Press-wedge (USG) were simple in design and offered excellent possibilities for commercial introduction. These three machines can be easily manufactured in most developing countries and could be marketed to farmers at a reasonable price of about US$50 to US$60. It was decided to further test and improve these machines through yield trials during the 1983 wet season in cooperation with the following groups:

a) The IRRI Agronomy Department at the IRRI Farm and at the Maligaya Research Station.

b) The IRRI Training & Technology Transfer Department at various research stations and farmers' fields in the Philippines.

c) The Ministry of Food & Agriculture, Govt. of the Philippines at various research sites.

d) The IRRI Agricultural Engineering Department in nine progressive farmers' fields in Laguna Province.

The three machines are now undergoing continuous improvements on the basis of feedback being received from field trials. As of this writing, yield data from the nine cooperating farmers in Laguna has been obtained by the IRRI Agricultural Engineering Department. The results are presented in Tables 1 and 2.

The farmer trials indicate that in all nine cases, a single application by any of the three machines increased fertilizer use efficiency in every case when compared to farmers' traditional practice of split surface broadcast application. The average increase in fertilizer use efficiencies for the three machines on clayey soils at the nine farm locations in Laguna were as follows:

1)	Straight Auger Applicator	Prill	49.82%
2)	Oscillating Plunger Applicator	Prill	44.49%
3)	Press-wedge Applicator	USG	51.29%

Each of the nine farmers were pleased with the wet season results and have requested to use these machines in the coming dry season.

Results from the other IRRI departments and outside agencies who are testing these applicators in different parts of the country are expected to be available by the end of this year. On the basis of the experience gained so far, one can conservatively estimate that fertilizer savings of approximately 35% could be easily achieved through the use of these machines. Hopefully, by the end of this year, we will have additional results from other test sites and more precise estimates on fertilizer savings that could be achieved.

It is not clear at this moment whether farmers would prefer to save on fertilizer costs or go for maximization of yields. The nine cooperating progressive farmers in Laguna were used to applying fairly high fertilizer rates. They expressed a preference for increased yields rather than fertilizer savings. Since fertilizer efficiencies generally show greater increases at low fertilizer rates, perhaps the less progressive farmers would prefer to save fertilizer rather than increase yields. The rapidly increasing prices of fertilizer in the Philippines and farmers capital constraints may automatically force an input saving rather than a yield maximizing strategy for the near future.

At this stage, it would be appropriate to compare the three new applicators with the original target specifications that were developed in consultation with concerned IRRI scientist at the start of this crash program to develop deep placement applicators. Table 3 lists the Essential, Desirable and Undesirable Target Specifications along with an assessment of how the new machines have been able to meet the original objectives. The table includes a fourth machine, the Deep Plunger Applicator (USG), which was the best performing applicator in 1982. It is interesting to note that the three new machines have not only met all the essential specifications but exceeded three of these beyond their desired limits.

It is hoped that by the end of 1983, the three machines would have been sufficinetly tested and improved under different soil and water conditions for limited commercial production release in the Philippines and for extensive farm trials in other Asian countries. If these trials prove conclusive, the designs of these applicators will be released by late 1984 to selected manufacturers in Asia for regular commercial production.

CONCLUSIONS

The machine reported here have demonstrated a rather encouraging performance in the various tests and field trials that have been conducted so far. We are confident that with the development of these three applicators, the primary hurdle of deep placement of prilled and supergranular urea has essentially been overcome. What remains now, is the extensive evaluation and adaptation of these applicators to suit farmer preferences, varying site, soil and cultural differences in the major rice growing countries of Asia.

Introduction of these machines to farmers through normal manufacturing and commercial channels will require substantial agricultural and industrial extension efforts from IRRI, National Agricultural Agencies and Fertilizer Manufacturers in the rice growing countries. While the introduction of deep placement applicators seems to be the solution for improving fertilizer use efficiencies, there is little doubt in my mind that these machines will be used mostly by the more affluent farmers. Majority of the small subsistent farmers will not have the resources to purchase machines. Such farmers will either have to rent these machines or alternate non-mechanical methods must be developed to improve their fertilizer use efficiencies. Use of irrigation water to deep place fertilizer and low cost fertilizer coatings such as clay, starch, oil, etc. to momentarily arrest fertilizer dissolution, offer some interesting possibilities for improving fertilizer use efficiencies without resorting to special machines.

The progress achieved during the last one year at IRRI on the development of deep placement applicators, specially for prilled urea, has been most challenging and satisfying to those of us who have been associated with this project. There are a number of strategic steps which led to the rapid development of the deep placement applicators that are reported in this paper. These steps included, the precise definition of the deep placement applicator problem; the prioretization of the technical and market criteria for applicators; the better understanding of the N transfer to floodwater during deep placement; the separate optimization in the laboratory of the individual components of applicators, the shortening of the applicator evaluation process through floodwater N measurement; the development of a large number of the applicator concepts which led to the design of the three promising machines and finally the dedicated efforts of the Design engineers and staff of the IRRI Agricultural Engineering Department who helped in the development of these applicators.

The assistance provided by the IRRI Agronomy Department, the Training & Technology Transfer Department and the Test Section of the Agricultural Engineering Department in testing and evaluation of the applicators, the IRRI Analytical Service Laboratory in analyzing floodwater samples and informal suggestions of some of my IRRI colleagues which helped in many ways is gratefully acknowledged.

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Table 1

DEEP PLACEMENT FERTILIZER APPLICATOR TRIALS[1] IN FARMERS' FIELDS
CALAMBA & CALAUAN, LAGUNA - 1983 WET SEASON
IRRI AGRICULTURAL ENGINEERING DEPT.
NOVEMBER 1983

No.	Farmer-Cooperator Name & Address	Variety	Application Method[2]	Fertilizer		Projected Yield[3] Tons/ha	Fertilizer Efficiency[4]	
				Material	Rate Kg N/ha		Kg Rough Rice/kg N	% Change Over Control
1	Mr. V. Oruga Bo. Mabacan Calauan, Laguna	Sinang-Domeng (HYV)	Farmer Practice (no machine - control)	Prill	90	4.87	54.11	-
			Spring Auger	Prill	47	4.42	94.04	+ 73.79
			Oscillating Plunger	Prill	48	3.95	68.10	+ 25.85
			Press-wedge	USG	48	3.82	79.58	+ 47.07
2	Mr. P. Macatangay Bo. Mabacan Calauan, Laguna	Sinang-Domeng (HYV)	Farmer Practice (no machine - control)	Prill	78	4.98	63.85	-
			Spring Auger	Prill	55	5.03	91.45	+ 43.22
			Oscillating Plunger	Prill	58	5.17	89.14	+ 39.61
			Press-wedge	USG	48	5.03	109.73	+ 64.12
3	Mr. J. Espinili Bo. Mabacan Calauan, Laguna	Sinang-Domeng (HYV)	Farmer Practice (no machine - control)	Prill	78	6.87	88.08	-
			Spring Auger	Prill	42	5.46	130	+ 47.59
			Oscillating Plunger	Prill	41	5.01	122.20	+ 38.74
			Press-wedge	USG	42	5.01	119.28	+ 35.42
4	Mr. S. Ilagan Bo. Mabacan Calauan, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	78	4.76	61.02	-
		C-4	Spring Auger	Prill	52	3.42	65.77	+ 7.98
		IR-42	Oscillating Plunger	Prill	39	4.42	113.33	+ 85.73
		IR-42	Press-wedge	USG	41	4.30	104.88	+ 71.88
5	Mr. C. Pabro Bo. Mabacan Calauan, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	80	4.28	53.5	-
			Spring Auger	Prill	66	4.92	75.54	+ 39.33
			Oscillating Plunger	Prill	58	4.03	69.48	+ 29.87
			Press-wedge	USG	45	4.06	90.22	+ 68.64
6	Mr. R. Vergara Bo. Mabacan Calauan, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	78	4.66	59.74	-
			Spring Auger	Prill	47	4.28	91.06	+ 52.43
			Oscillating Plunger	Prill	50	4.20	84.00	+ 40.61
			Press-wedge	USG	44	4.38	99.54	+ 66.62
7	Mr. L. Casubha Bo. Parian Calamba, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	67	5.47	81.64	-
			Spring Auger	Prill	40	5.19	129.75	+ 58.93
			Oscillating Plunger	Prill	53	5.03	94.91	+ 16.25
			Press-wedge	USG	51	4.58	89.80	+ 10.00
8	Mr. R. Isip Bo. Parian Calamba, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	78	5.74	73.59	-
			Spring Auger	Prill	40	5.25	131.25	+ 78.35
			Oscillating plunger	Prill	46	5.21	113.26	+ 53.91
			Press-wedge	USG	47	5.37	114.26	+ 55.26
9	Mr. C. Oleta Bo. Parian Calamba, Laguna	IR-42	Farmer Practice (no machine - control)	Prill	68	5.71	69.26	-
			Spring Auger	Prill	45	4.58	101.78	+ 46.95
			Oscillating Plunger	Prill	47	5.53	117.66	+ 69.88
			Press-wedge	USG	48	4.74	98.75	+ 42.58

[1] Except for application methods & fertilizer rates each farmer applied his own traditional cultural practices on all of 4 treatments.

[2] With machine applications, all fertilizer was applied as a single dose at 10 to 18 days after transplanting. Farmer practice varied but generally included 2 to 3 split broadcast applications.

[3] Based on 4 sampling sites (projected value at 14% m.c.).

[4] For lack of better methods of assessment, fertilizer efficiencies at different fertilizer rates have been compared.

Table 2

SUMMARY RESULTS OF INCREASES IN FERTILIZER USE EFFICIENCIES[1/]
WITH DEEP PLACMENT APPLICATORS ON NINE COOPERATING FARMERS
IN LAGUNA, PHILIPPINES

IRRI Agricultural Engineering Department
November 1983

		Percent Increase Over Farmer Split Broadcast Practice		
		Straight Auger Applicator Prill	Oscillating Plunger Applicator Prill	Press-Wedge Applicator USG
1	Mr. V. Oruga Bo. Mabacan Calauan, Laguna	73.79[2/]	25.85[2/]	47.07[2/]
2	Mr. P. Macatangay Bo. Mabacan Calauan, Laguna	43.22	39.61	64.12
3	Mr. J. Espinili Bo. Mabacan Calauan, Laguna	47.59	38.74	35.42
4	Mr. S. Ilagan Bo. Mabacan Calauan, Laguna	7.98[3/]	85.73	71.88
5	Mr. C. Pabro Bo. Mabacan Calauan, Laguna	39.33[4/]	29.87[4/]	68.64
6	Mr. R. Vergara Bo. Mabacan Calauan, Laguna	52.43[4/]	40.61[4/]	66.62[4/]
7	Mr. L. Casubha Bo. Parian Calamba, Laguna	59.93[4/]	16.25	10.00
8	Mr. R. Isip Bo. Parian Calamba, Laguna	78.35	53.91	55.26
9	Mr. C. Oleta Bo. Parian Calamba, Laguna	46.95	69.88	42.58
	Average Increase	49.82	44.49	51.29

[1/] Due to lack of better methods for comparative assessment, efficiencies at different fertilizer rates have been compared.

[2/] Plots were affected by stemborer infestation.

[3/] C-4 variety was used with this machine only & the crop lodged.

[4/] Deep-placed plots recovered from field submergence of 2 to 3 days during typhoon.

Table 3

COMPARATIVE DESIGN FEATURES OF IRRI DEVELOPED DEEP PLACEMENT FERTILIZER APPLICATORS

TARGET SPECIFICATIONS 1/	STRAIGHT AUGER (PRILL) COMPARATIVE ASSESSMENT 2/				OSC. PLUNGER (PRILL) COMPARATIVE ASSESSMENT 2/				PRESS WEDGE (USG) COMPARATIVE ASSESSMENT 2/				DEEP PLUNGER (USG) COMPARATIVE ASSESSMENT 2/			
	EX.	W.M.	P.M.	N.M.	EX.	W.M.	P.M.	N.M.	EX.	W.M.	P.M.	N.M.	EX.	W.M.	P.M.	N.M.
ESSENTIAL																
• MUST APPLY PRILLED FERTILIZER 5 to 10 CM DEEP		✓				✓				✓				✓		
• CONTINUOUS (NON-INTERMITTENT) OPERATION		✓				✓				✓						✓
• MUST APPLY COMM'L GRADE FERTILIZER W/O GRADING		✓				✓				✓						✓
• RATE 45 & 75 KG N/HA (2 to 3 BAGS)		✓				✓			✓	✓					✓	
• MUST FUNCTION IN UP TO 5 CM DEEP STANDING WATER		✓				✓				✓				✓		
• MUST APPLY 5 to 20 DAYS AFTER TRANSPLANTING		✓				✓				✓					✓	
• LABOR INPUT 8-12 HRS/HA PER APPLICATION			✓				✓				✓					✓
• LIGHT (10-18 KG) FOR LIFTING AT END OF ROWS	✓				✓				✓						✓	
• APPROXIMATE SELLING PRICE - US $ 50-100	✓				✓				✓							✓
• MUST ADEQUATELY SEAL PLACEMENT OPENING	✓				✓					✓				✓		
• STURDY TO LAST AT LEAST 4-6 SEASONS		✓				✓				✓				✓		
• PULLING OR PUSHING FORCE OF 7 to 10 KG		✓				✓				✓				✓		
• SMOOTH UNIDIRECTIONAL MOVEMENT		✓				✓				✓						✓
DESIRABLE																
• COULD BE USED FOR BOTH PRILLED/USG OR FG/USG				✓				✓			✓					✓
• ROTARY RATHER THAN OSCILLATING MECHANISM		✓				✓				✓						✓
• ROLLING ON WHEELS RATHER THAN ON SKIDS				✓				✓				✓				✓
• PUSH-TYPE FOR POST-TRANSPLANT OPERATION		✓				✓				✓				✓		
• MULTI-ROW OPERATION - 2 to 4 ROWS			✓				✓				✓				✓	
• NON-FURROW OPENER TYPE				✓				✓				✓		✓		
• MECHANICAL INJECTOR TYPE		✓				✓						✓		✓		
• EASY TO MANUFACTURE BY SMALL SHOPS		✓				✓				✓				✓		
• NOT NEED HIGH PRECISION IN PRODUCTION		✓				✓			✓					✓		
• PULL TYPE FOR PRE-TRANSPLANT OPERATION				✓				✓				✓				✓
• CAN ALSO BE USED FOR RANDOM SEEDED CROP				✓				✓				✓				✓
UNDESIRABLE																
• INTERMITTENT OPERATION		✓				✓				✓						✓
• MULTI-DIRECTION ACTION DURING OPERATION		✓				✓				✓						✓
• USED OF LIQUID CONVEYING MECHANISM		✓				✓				✓				✓		
• COMPLEX MECHANISMS		✓				✓				✓				✓		
• DELICATE MECHANISMS		✓				✓				✓				✓		

1/ THE TARGET SPECIFICATIONS WERE DEVELOPED IN NOV. 1982 AFTER CONSULTATION WITH CONCERNED IRRI SCIENTISTS.

2/ EX. = EXCEEDED; W.M. = WELL MET; P.M. = PARTIALLY MET; N.M. = NOT MET

DATE: NOV. 10, 1983

Fig. 1a. Avenues for fertilizer transfer to floodwater during deep placement

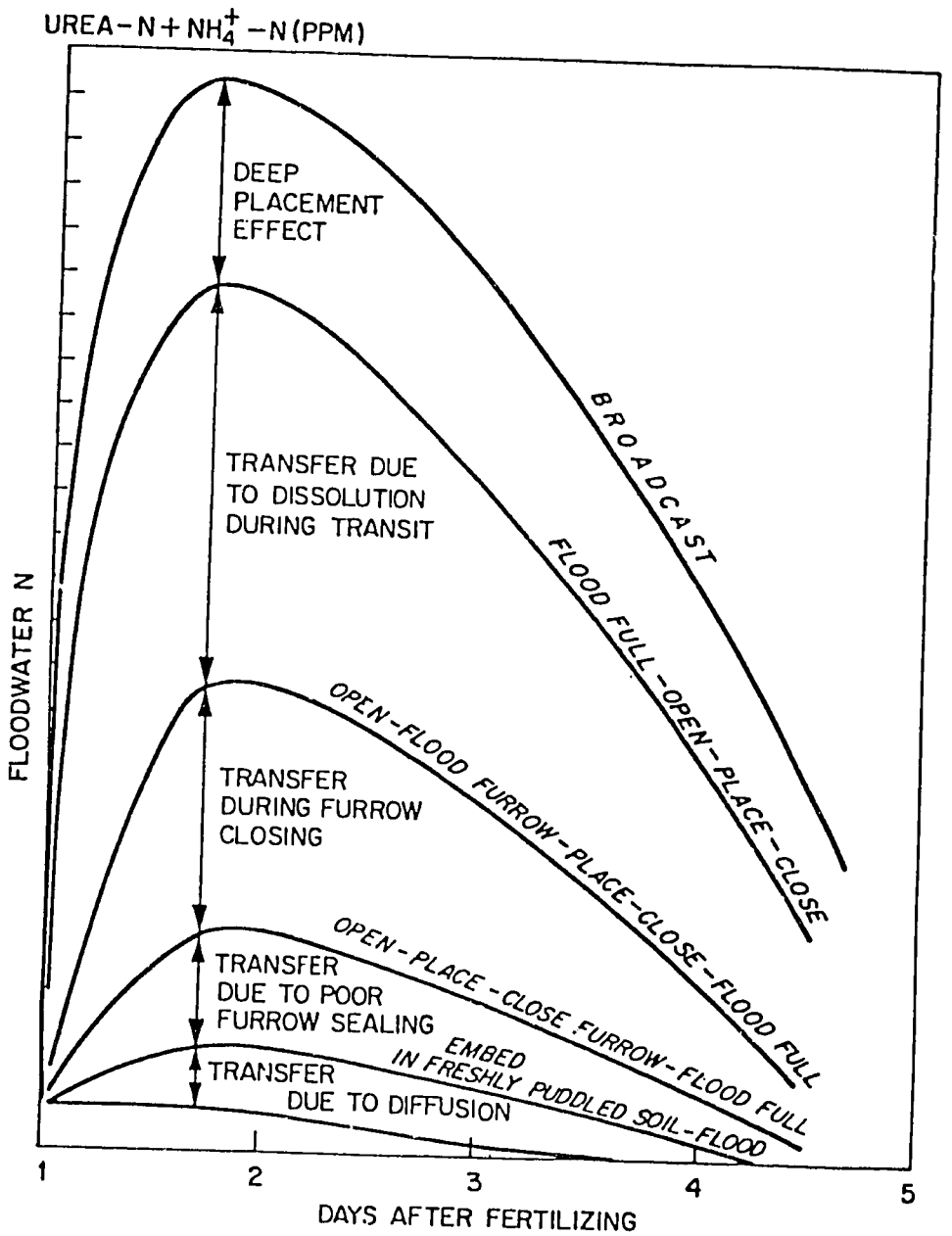

Fig. 1b. HYPOTHETICAL CURVES SHOWING POSSIBLE AVENUES AND EXPERIMENTAL TECHNIQUES FOR EVALUATING FERTILIZER TRANSFER TO FLOODWATER DURING PLACEMENT.

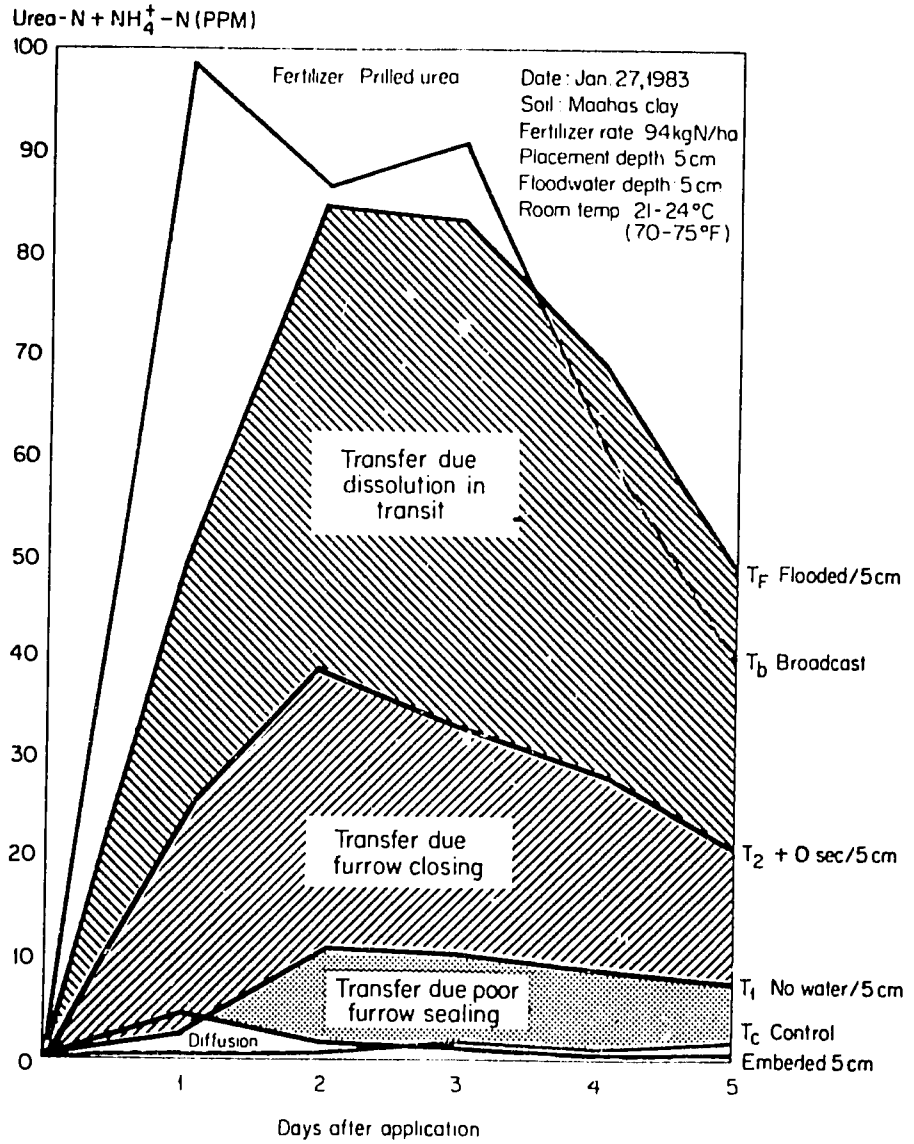

Fig. 1c. Major avenues for N transfer to floodwater during prilled urea placement at 5 cm depth in flooded Maahas clay. (Ag. Eng'g.)

Fig. 2 Straight auger applicator for prilled urea.

Fig. 3 Oscillating plunger applicator for prilled urea.

Fig. 4 Press-wedge applicator for urea supergranules (USG).