g soil; N, 0.26%; available P, 21ppm; and available Zn, 0.45ppm. The soil texture and organic matter, were determined following the Pipette sampling method and walkley and Black's wet oxidation method, respectively, as described by Piper (1950). Total N was estimated following semi micro kjeldahl method while the CEC, available P and available Zn were determined on sodium saturation, $NaHCo_3$ extraction and 0.05 N HCL extraction of soil, respectively, following the methods as outlined by Black (1965).

The experiment was laid out in Randomized Block design with four replications. The fertilizer treatments were as follows :

T_1 : Control (no Zn application)
T_2 : 10 kg Zn/ha mixed with soil
T_3 : 20 kg Zn/ha mixed with soil
T_4 : 40 kg Zn/ha mixed with soil
T_5 : Root dipping in 1.6% Zn solution just before planting
T_6 : Foliar sprays at the rate of 1 kg Zn/ha after 9 weeks of transplantation.

The treatment T_5 was selected on the basis that the IRRI scientists recommended root dipping of rice seedling in 1.6% Zn solution and the treatment T_6 was chosen as per suggestion of IAEA experts.

Zinc was supplied as $ZnSo_4$ and no other chemical fertilizers and manures were used in these treatments.

Five hills of the crop per plot were harvested at panicle initiation stage and the rest at maturity. The dry matter as well as the grain and straw yields were recorded on oven-dry basis (65°C). The plants were analysed at both stages for Zn and P contents after wet digestion of the samples with ternary acid mixture (HNo_3 -- H_2So_4 — $HClo_4$) following the procedure described by Chapman and Pratt (1961). The up take of Zn and P by plant was calculated from the data on yield and Zn and P content of the crop.

RESULTS AND DISCUSSION

Plant height

Results in Table I show that plant height increased significantly due to application of Zn. But Duncan's test indicates that plant height although increased significantly due to all the Zn treatments over control, it did not differ significantly with the variation of the doses and methods of Zn application. It was also observed that when Zn was applied to soil the plant height showed increase upto 20 kg Zn/ha to be followed by slight decrease at 40 kg Zn/ha. The heighest plant height of 116 cm was noted with 20 kg Zn/ha supply.

Number of tillers

The number of tillers showed marked increase due to Zn application (Table I) It was noted that all the Zn treatments produced significantly higher number of tillers over control. However, soil

treatment with 20 kg Zn/ha was on par with soil treatments with 40 kg Zn/ha but superior to rest of the Zn treatments in producting tillers of the rice plant. The highest number of tillers per hill was 26.3 recorded in 20 kg Zn/ha application.

Dry matter yield

From the data reported in Table I it is apparent that application of Zn caused significant increase of dry matter yield of the crop. The highest dry matter yield of 65.8 g/5 hills was noted due to 20 kg Zn/ha application but higher dose of 40kg Zn/ha showed depressing effect on dry matter production. Results of Duncan's test suggest that soil application of Zn at the rate of 20kg Zn/ha is the superior practaice in producing drymatter yield of the crop. Soil application of 40 kg Zn/ha produced the similar results as in root dipping or spray application of Zn. Giordano and Mortvedt (1973) reported that there was significant effect of Zn application on dry matter production of rice.

Panicle length, number of grains per panicle and 1000 grain weight :

It appears from the data in Table I that the different methods and doses of Zn application could not produce significant effect either on panicle length or number of grains per panicle or 1000 grain weight. But it is important to note that soil treatment of 20 kg Zn/ha recorded the highest plant height, the highest number of tillers and the highest dry matter yield also produced the highest panicle length (19.1 cm), the highest number of grains per panicle (89 4) as well as the highest 1000 grain weight (18.9 g).

Grain Yield

The Zn treatments produced a considerable increase in the grain yield of rice as indicated by the results in Table I. In the present study the highest grain yield of 33 16 kg/ha (85% increase over control) was recorded in Soil application of Zn at the rate of 20kg Zn/ha. Duncan's test shows that the soil application of Zn at the rate of 20 kg Zn/ha was superior to other treatments. Giordano and Mortvedt (1972) studied the effects of of Zn on rice and reported that Zn was most effective when mixed with the soil.

Straw Yield

Data on straw yield showed significant positive response to Zn application. The highest straw yield was 4042 kg/ha (47% increase over control) recorded under soil application of 20 kg Zn/ha. The use of higher dose of 40 kg Zn/ha applied to soil showed depressing effect on yield. All the Zn treatments except root dipping were superior to control (Table I).

Zn and P content

It was observed that the application of $ZnSo_4$ resulted in a significant increase in Zn content of second leaf

TABLE I Effect of $ZnSo_4$ application on different growth parameters and yield of Tepi boro rice (Mean of 4 replicates)

Treatement	Plant height (cm)	No. of tillers/ hill	Dry matter yield at panicle initiation stage (g/5 hills)	Panicle length (cm)	No. of grains/ panicle	1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1	99.0 b	17.8 d	42.4 c	17.7	67.8	17.1	1783 e	2743 d
T_2	110.1 a	22.0 bc	45.6 c	18.5	79.9	18.0	2855 b	3493 bc
T_3	116.0 a	26.3 a	65.8 a	19.1	89.4	18.0	3316 a	4042 a
T_4	114.8 a	24.3 ab	53.8 b	18.3	73.5	18.8	2371 c	3337 bc
T_5	113.0 a	21.5 bc	47.0 bc	19.1	86.6	17.4	1922 de	2999 cd
T_6	108.3 a	19.3 c	49.0 bc	18.5	76.4	17.3	2162 cd	3631 ab
S.E.	2.85	0.97	2.39				90.54	156.65
C.D. (P=0.05)	8.52	2.90	7.15				270.13	467.39

In a column, the figures having common letter (s) do not differ significantly at 5% level

and of whole plant without second leaf at panicle initiation stage of the crop (Table II). The highest Zn content of second leaf (32.7 ppm) was observed at 10 kg Zn/ha application. An examination of the effects of the methods of Zn application indicated a significant increase in Zn content due to soil application and root dipping over spraying. The highest Zn content of whole plant without second leaf (34.2 ppm) was found in 20 kg Zn/ha application and the lowest (19.4 ppm) in control. In this case, there was no significant difference between spray treatment and control.

Results in Table II showed significant effect of Zn fertilization on Zn content of rice grain but insignificant effect in case of rice straw. The Zn content of rice grain ranged from 9.2 ppm in spray application of Zn to 14 0 ppm in 40 kg Zn/ha soil application. Duncan's Multiple Range Test reveals that soil application and and root dipping methods were statisitically superior to spraying. The results in Table II indicate that plant P content was not affected by the rates and methods of Zn application. If appears from the results in Table III that there was significant effect of different Zn treatments on the

TABLE II Effect of $ZnSo_4$ application on Zn and P content in Tepi boro rice at different stages of growth.

(Mean of 4 replicates)

Treatment	Second leaf at Panicle initiation stage		Plant without second leaf at panicle initiation stage		Rice grain at harvest		Rice straw at harvest	
	Zn (ppm)	P (ppm)	Zn (ppm)	P (ppm)	Zn (ppm)	P (ppm)	Zn (ppm)	P (ppm)
T_1	24.3 b	2250	19.4 c	2250	10.7 b	2072	9.8	1096
T_2	32.7 a	2162	31.9 a	1937	11.3 b	2218	10.3	1165
T_3	32.2 a	1975	34-2 a	2012	12.0 b	2112	12.8	1158
T_4	24.7 b	1875	31.6 a	1875	14.0 a	2112	10.6	1052
T_5	30.8 a	2075	25.6 b	2207	11.6 a	2153	11.8	1210
T_6	21.6 c	2300	19.5 c	2212	19.2 c	2291	13.5	1305
S.E.	0.87		1.29		0.48			
C.D. (P=0.05	2.59		3.87		1.45			

In a column, the figures having common letter (s) do not differ significantly at 5% level

uptake of Zn and P nutrients both by grain and straw of the crop. The soil application of 20 kg Zn/ha caused significantly higher Zn and P uptake by the plant over control and other rates of soil application of Zn. Although Zn uptake due to T_2 and T_4 treatments was identical but P uptake in T_4 treatment was markedly lower than that in T_2 treatment (Table III). The root dipping treatment (T_5) failed to show any reliable effect on Zn and P uptake by the plant over control where as the spray application of Zn showed similar effect as noted in soil application of 10 kg Zn/ha on the uptake of these nutrients by the plant. The highest recovery of Zn and P by plant as recorded in soil application of 20 kg Zn/ha was 0.092 kg/ha and 11.67 kg/ha, respectively. It may be mentioned here that there was narrow difference between Zn contents in grain and straw but much higher straw yield resulted in considerable higher Zn uptake by straw than by grain. Again, P content in grain was nearly double than that in straw. The results in Table III further reveal that although Zn uptake by whole plant at harvest due to different Zn treatments was remarkably higher than that in control, the total Zn uptake by plant was

TABLE III Effect of $ZnSo_4$ application on Zn and P uptake by Tepi boro rice
(Mean of 4 replicates)

Treatment	Zn uptake by grain (kg/ha)	Zn uptake by straw (kg/ha)	Zn uptake by whole plant (kg/ha)	P uptake by grain (kg/ha)	P uptake by straw (kg/ha)	P uptake by whole plant (kg/ha)
T_1	0.019 b	0.027 b	0.046 c	3.69 d	2.99 d	6.68 d
T_2	0.032 ab	0.036 b	0.068 b	6.31 b	4.05 bc	10.36 b
T_3	0.040 a	0.052 a	0.092 a	6.99 a	4.68 ab	11.67 a
T_4	0.033 ab	0.035 b	0.068 b	5.00 c	3.50 cd	8.50 c
T_5	0.022 ab	0.035 b	0.057 bc	4.13 d	3.63 cd	7.76 cd
T_6	0.020 ab	0.050 a	0.070 b	4.95 c	4.79 a	9.74 b
S.E.	0.008	0.004	0 005	0.20	0.23	0.38
C.D. (P=0.05)	0.024	0.012	0.015	0.61	0.70	1.16

In a column, the figures having common letter (s) do not differ significantly at 5% level of significance

only a small fraction of the amount supplied.

Thus, it may be suggested that Zn deficiency which is likely to occur in rice soils high in organic matter and in continously flooded areas can be overcome by judicious use of Zn in the form of $ZnSo_4$.

REFERENCES

BLACK, C. A., Methods of soil Analysis, 1965. Part I and 2. *Amer. Sci. Agro. Inc. Publisher.*

CHAPMAN, H. D. and P. F., PRATT, 1961. Methods of Analysis for Soils, Plants and waters. *Univ. Cal. Div. Agri. Sci.*

CASTRO, R. U., 1977. Zinc deficiency in rice: A review of research at the international Rice Research Institute. *Int. Rice. Res. Inst. Res.* Paper Series 9 : 18.

GIORDANO, P. M. and J. J. MORTVEDT, 1972. Rice respone to Zinc in Flooded and non – flooded soil. *Agron. J.* **64** : 521—24

GIORDANO, P. M. and J. J. MORTVEDT. 1973 Zinc sources and methods of application for rice *Agron. J.* **65** : 51 — 53.

IRRI Annual Report, 1975. Tolerance to Zinc deficiency. Los Banos, philippines, pp. 167—68.

PIPER, C. S., 1950. Soil and Plant Analysis. Adelaide Univ. Press., Australia.

TANAKA, A. and S. YOSHIDA, 1970. Nutritional disorders of rice plants in Asia. Tech. Bull. 10. IRRI. Philippines.

YOSHIDA, S. and A. TANAKA, 1962. Zinc deficiency of the rice plant on calcareous soils. *Soil Sci. Pl. Nutr.* **15**: 75—80.

YOSHIDA, S., G. W. MCIEAN, and M. SHAFI, K. F. MUELLER, 1970. Effects of different methods of zinc application on growth and yields of rice in a calcareous soil. West Pakistan *Soil Sci. Plant Nutr.* **16**: 147 — 49.