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Research Paper

Effect of balanced nutrition on nitrogen-use efficiency, N balance and productivity of maize (*Zea mays*) in *Inceptisol* and *Alfisol* of Tamil Nadu

M. PARAMASIVAN[1], P. MALARVIZHI[2] AND S. THIYAGESHWARI[3]

Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu 641 003

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ABSTRACT

A field experiment was conducted during July–October of 2006 and 2007 at Department of Soil Science and Agricultural Chemistry, Coimbatore, to study the effect of balanced fertilization on yield of hybrid maize (*Zea mays* L.), nitrogen-use efficiency and N balance in Mayamankuruchi and Madukkur soil series (*Inceptisol* and *Alfisol*) of Tamil Nadu. The experiments was conducted in randomized block design with 13 treatments comprising different levels of N, P and K with Zn as inorganic fertilizers. The treatments were replicated thrice. The range of partial factor productivity (PFP) was from 18.9–45.0 kg grain/kg nitrogen applied to hybrid maize in Mayamankuruchi soil series and 18.7–44.3 kg/kg (N) in Madukkur soil series. The agronomic efficiency varied from 4.9–24.2 and 5.2–24.3 kg grains/kg N in Mayamankuruchi and Madukkur soil series respectively. The highest values (86.3 and 94.9 kg/kg (N) of physiological efficiency were registered in the treatments omitting Zn in both series soil. The fraction of applied N that is absorbed by a crop is expressed as apparent N recovery. The mean recovery efficiency for applied N ranged from 29.5–85.6% and 28.6–81.3% for the two soils. The net positive nitrogen balance was found in Mayamankuruchi soil series and the negative nitrogen balance in Madukkur soil series.

Key words : Alfisol, Inceptisol, Maize, Nitrogen, Nitrogen balance, N-use efficiency

In India, maize is cultivated in an area of 8.78 million ha with a production of 21.76 million tonnes and the average yield is 2.48 tonnes/ha (DMR, 2012). In Tamil Nadu, it is cultivated in an area of 0.24 million ha with a production of 1.14 million tonnes and an average productivity of 4.66 tonnes/ha (DES, 2010). By 2020, the requirement of maize for various sectors will be around 100 million tonnes. Future sustainability of maize production will greatly depend on the improvement in soil resources base through the balanced fertilization. The timely application of all essential plant nutrients in readily available form, in optimum quantities and in the right proportion, through the correct method, suitable for specific soil/crop conditions are major components in balanced fertilization for achieving the higher productivity.

Nitrogen-use efficiency (NUE) which is expressed as grain yield in kg/kg of N applied as fertilizer hardly exceeds 50% in cereal crops. Under field conditions, NUE varies from 25 to 40% in rice and 40 to 60% in other crops, with a global average of about 50% (Mosier, 2002), maize being no exemption. It is controlled mainly by following factors such as crop N demand, supply of N from soil and fertilizers and losses of N from the soil-plant system. Imbalanced and inappropriate use of N and other nutrients, such as potassium in different agro-ecosystem, can also modify NUE. The on-farm experiments in Asia has indicated that NUE on average can be increased by 18% in maize by the application of appropriate amount of nutrients (Yadav *et al.,* 2007).

Balanced fertilization is the key to achieve higher productivity and nutrient-use efficiency. There is a growing deficiency of macro-and micronutrients due to intensive cropping with use of high-analysis fertilizers. Proper soil diagnosis and adoption of site-specific nutrient and crop management ushers in highest productivity, efficiency and profitability. The concept of balanced fertilization paves the way for optimum plant nutrient supply to realize full yield potential of crop. However, continuous use of imbalance fertilizers causes decline in soil fertility and yield reduction. Keeping these points in view, the present study was undertaken to investigate the effect of balanced fertilization on yield of maize, soil fertility, nitrogen-use efficiency and N balance in Mayamankuruchi (Myk) soil se-

[2]**Corresponding author Email:** paramusoil@gmail.com
[1]Assistant Professor (SS&AC), Agricultural College & Research Institute, Killikulam; [2]Professor (SS&AC), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu 641 003; [3]Professor (SS&AC), Agricultural College and Research Institute, Madurai, Tamil Nadu

ries of order *Inceptisols* and in Madukkur (Mdk) soil series of order of *Alfisols*. These are the major maize-growing soils in Tirunelveli, Thoothukudi, Madurai, Dindigul, Theni, Coimbatore, and Trichy districts of Tamil Nadu.

MATERIALS AND METHODS

The Mayamankuruchi series is a member of fine, mixed, isohyperthermic family of *Typic* Haplusteps. Typically this soil series is sandy loam to sandy clay loam, neutral to non-calcareous in A horizon, clay loam to clay or gravelly clay, mild alkaline in B horizon, moderately well-drained with neutral to mildly alkaline, deep with moderately rapid permeability. The soil reaction was 8.07 and the soluble salt content is within the permissible limits. The cation-exchange capacity of the soil was 31.2 c mol (p^+)/kg. The soil was low in available nitrogen (230.3 kg/ha) and medium in available phosphorus (18.4 kg/ha) and high in available potassium (292 kg/ha). It contained 31.5 c mol (p^+)/kg exchangeable Ca and 6.7 c mol (p^+)/kg exchangeable Mg. The available Zn, Fe, Cu and Mn were 2.91, 42.5, 4.26 and 20.4 mg/kg respectively. The Madukkur series is a member of fine loamy, mixed isohyperthermic family of *Udic* Haplustalfs. Typically this series soils are sandy loam to sandy clay loam surface texture neutral non-calcareous in A horizon; sandy clay loam to clay loam B horizon overlaying, moderately well-drained with neutral non-calcareous very deep with rapid permeability. The soil reaction observed was 6.75, whereas the soluble salt content is within the permissible limits. The cation-exchange capacity of the soil was 14.3 c mol (p^+)/kg. The low availability of N (148.0 kg/ha), medium availability of P (14.0 kg/ha) and K (242.0 kg/ha) were the fertility status of this soil. The available Zn, Fe, Cu and Mn content were 2.6, 41.1, 4.4 and 15.3 mg/kg respectively.

The field experiment was conducted during July–October of 2006 and 2007 at the farmers' field in both soil series with maize 'COHM 5' at Ramayanpatti village in Tirunelveli district and Unchini village in Sendurai taluk of Perambalur district of Tamil Nadu. The field experiment consisted of 13 treatment combinations as follows:

The treatments were replicated 3 times in randomized block design (RBD). The crop was sown at 60 cm × 25 cm spacing in 20 m^2 plot (5 m × 4 m) in the first week of July and harvested in the third week of October. The cultivation practices were followed as per the guidelines of Crop Production Guide of Tamil Nadu Agricultural University. The fertilizer sources used were urea for N (46% N), single superphosphate for P (16% water-soluble P_2O_5), muriate of potash for K (60% of K_2O) and zinc sulphate for Zn (22% Zn). Full dose of P, K and Zn and one-third of N were applied basal to maize at the time of sowing. The remaining dose of N was top-dressed in 2 equal splits–25 and 45 days after sowing. Yield and dry matter production (DMP) were recorded as per standard procedures. The nutrient content and uptake by maize were analysed through prescribed laboratory procedures. The post-harvest soil samples were collected from 0–20 cm depth for analysing available nutrient status. Soil samples were analysed for alkaline permanganate oxidizable N. Nutrient-use efficiency (kg grain/kg nutrient) was calculated by dividing the grain yield with total nutrients. Fertilizer-use efficiency can be described as the output of economic produce by any crop/unit of fertilizer nutrient applied under specific set of soil and climatic conditions (Mikkelsen and De Datta, 1991).

The data on grain yield, amount of N applied through inorganic source and nitrogen uptake by the crop were used for deriving various N-use efficiencies of the hybrid maize. The efficiency with which the native and applied N through inorganic source used by the crop towards grain production was evaluated through parameters like partial factor productivity, agronomic efficiency and physiological efficiency and recovery efficiency and which were

Mayamankuruchi soil series	Madukkur soil series
T_1, $N_0P_2K_2$Zn as 0-64-48-4.8 kg/ha	T_1, $N_0P_2K_2$Zn as 0-70-150-9.6 kg/ha
T_2, $N_1P_2K_2$Zn as 150-64-48-4.8 kg/ha	T_2, $N_1P_2K_2$Zn as 150-70-150-9.6 kg/ha
T_3, $N_2P_2K_2$Zn (ONT) as 200-64-48-4.8 kg/ha	T_3, $N_2P_2K_2$Zn (ONT) as 200-70-150-9.6 kg/ha
T_4, $N_3P_2K_2$Zn as 250-64-48-4.8 kg/ha	T_4, $N_3P_2K_2$Zn as 250-70-150-9.6 kg/ha
T_5, $N_2P_0K_2$Zn as 200-0-48-4.8 kg/ha	T_5, $N_2P_0K_2$Zn as 200-0-150-9.6 kg/ha
T_6, $N_2P_1K_2$Zn as 200-48-48-4.8 kg/ha	T_6, $N_2P_1K_2$Zn as200-52.5-150-9.6 kg/ha
T_7, $N_2P_3K_2$Zn as 200-80-48-4.8 kg/ha	T_7, $N_2P_3K_2$Zn as 200-87.5-150-9.6 kg/ha
T_8, $N_2P_2K_0$Zn as 200-64-0-4.8 kg/ha	T_8, $N_2P_2K_0$Zn as 200-70-0-9.6 kg/ha
T_9, $N_2P_2K_1$Zn as 200-64-36-4.8 kg/ha	T_9, $N_2P_2K_1$Zn as 200-70-112.5-9.6 kg/ha
T_{10}, $N_2P_2K_3$Zn as 200-64-60-4.8 kg/ha	T_{10}, $N_2P_2K_3$Zn as 200-70-187.5-9.6 kg/ha
T_{11}, $N_2P_2K_2$ -Zn as 200-64-48-0 kg/ha	T_{11}, $N_2P_2K_2$ -Zn as 200-70-150-0 kg/ha
T_{12}, RDF as 135-62.5-50-5.5 kg/ha	T_{12}, RDF as 135-62.5-50-5.5 kg/ha
T_{13}, Absolute control	T_{13}, Absolute control

derived from the parameters of grain yield and N uptake by the crop. Partial factor productivity (P_{fp}) represents the combined effect of native as well as the applied N. It is the ratio of grain yield to the applied N and computed as Y/Nt. The term which represents the efficiency of applied nitrogen in terms of incremental efficiency from applied N is often called as the agronomic efficiency (ε_a) and computed as ΔY/Nt. The physiological efficiency (ε_p) is the efficiency with which the crop utilizes the acquired N to produce more grains and calculated as ΔY/ΔNu. The recovery efficiency (ε_R) is the percentage of N uptake from the applied N and derived as (ΔNu/Nt) × 100.

RESULTS AND DISCUSSION

Grain and dry matter yield

In Mayamankuruchi soil series, the highest grain yield and dry matter production were recorded with the application of 250:64:48:4.8 kg NPK Zn/ha (Table 1). The application of 200:64:48:4.8 kg NPK Zn/ha resulted in the next highest grain yield and dry matter production. The recommended dose of fertilizer recorded the lower grain yield and dry matter production than the treatment enhanced with N or P or K. Similar trend was observed in Madhukkur soil series. The highest grain yield and dry matter production were recorded with the application of 250:70:150:9.6 kg of NPK and Zn/ha (Table 2). The application of 200:70:150:9.6 kg of NPK and Zn/ha resulted in the next highest grain yield and dry matter production. The blanket recommendation recorded the lower grain yield and dry matter production than the treatment enhanced with N or P or K. The treatments omitted with N or P or K or Zn showed poor yield and which were very closer to the absolute control. The increase in grain yield of maize might be owing to the increased availability of essential nutrients from the enhanced level of nutrients applied to the crop. These findings closely confirm results of Verma *et al.* (2005) and Parasuraman (2006).

Nitrogen-use efficiency

Nutrient-use efficiency is conceived as the product of uptake efficiency, i.e. the ratio of actual uptake to potential supply, and utilization efficiency, i.e., the ratio of yield to actual uptake. Both depend on the availability of the nutrient in relation to other growth factors, and require N, P and K perfectly in balance to reach their maximum values (Janssen, 1998). In our study, the N-use efficiency has been assessed through partial factor productivity, agronomic efficiency, physiological efficiency and recovery efficiency.

Partial factor productivity: Partial factor productivity (PFP) for applied N is a useful measure of NUE because it provides an integrative index that quantifies total economic output relative to utilization of N in the system, including the indigenous soil N supply and applied N (Cassman *et al*., 1993). Partial factor productivity reflects both agronomic efficiency (AE) as well as the balance between the indigenous soil N supply and applied N. The partial factor productivity of hybrid maize varied from 18.9–45.0 kg/kg (N) in Mayamankuruchi soil series and 18.7–44.3 kg/kg (N) in Madukkur soil series. On an aver-

Table 1. Yield, economics and nitrogen-use efficiency of maize 'COH M 5' in Mayamankuruchi soil series (Inceptisols) (mean data of 2 years)

Treatment	Nutrient doses (kg/ha)	Grain yield (tonnes/ ha)	DMP (tonnes/ ha)	Cost of cultivation (×10³₹/ ha)	Gross returns (×10³₹/ ha)	Net returns (×10³₹/ ha)	Benefit: cost ratio	N uptake (kg/ha)	N-use efficiency, kg/kg (N)			
									PFP	AE	PE	RE (%)
$N_0P_2K_2Zn$	$N_0P_{64}K_{48}Zn_{4.8}$	3.22	9.41	19.4	24.3	4.9	1.25	72.5	0	0	45.0	0
$N_1P_2K_2Zn$	$N_{150}P_{64}K_{48}Zn_{4.8}$	6.17	16.42	21.0	46.2	25.1	2.20	149.9	41.1	22.4	79.7	67.8
$N_2P_2K_2Zn$ (ONT)	$N_{200}P_{64}K_{48}Zn_{4.8}$	7.26	19.48	21.6	54.4	32.9	2.52	219.4	36.3	22.3	65.2	85.6
$N_3P_2K_2Zn$	$N_{250}P_{64}K_{48}Zn_{4.8}$	8.00	22.39	22.1	60.2	38.1	2.72	260.8	32.0	20.8	66.2	85.1
$N_2P_0K_2Zn$	$N_{200}P_0K_{48}Zn_{4.8}$	3.78	11.68	20.5	28.8	8.3	1.40	109.6	18.9	4.9	54.8	30.7
$N_2P_1K_2Zn$	$N_{200}P_{48}K_{48}Zn_{4.8}$	6.31	16.42	21.7	46.9	25.1	2.16	160.1	31.5	17.5	72.4	66.0
$N_2P_3K_2Zn$	$N_{200}P_{80}K_{48}Zn_{4.8}$	7.07	18.32	22.5	52.8	30.3	2.34	209.3	35.4	21.3	62.1	80.6
$N_2P_2K_0Zn$	$N_{200}P_{64}K_0Zn_{4.8}$	3.95	11.04	21.2	29.7	8.5	1.40	107.1	19.7	5.7	46.1	29.5
$N_2P_2K_1Zn$	$N_{200}P_{64}K_{36}Zn_{4.8}$	6.23	16.16	21.5	46.3	24.8	2.15	157.6	31.1	17.1	71.7	54.7
$N_2P_2K_3Zn$	$N_{200}P_{64}K_{60}Zn_{4.8}$	7.17	18.92	21.7	52.9	31.3	2.44	211.5	35.8	21.8	64.9	81.7
$N_2P_2K_2$ -Zn	$N_{200}P_{64}K_{48}$ -Zn_0	5.86	15.11	21.0	43.7	22.7	2.08	113.9	29.3	15.3	79.3	32.9
Blanket	$N_{135}P_{62.5}K_{50}Zn_{5.5}$	6.08	15.64	20.9	45.2	24.4	2.16	132.5	45.0	24.2	86.3	62.5
Control	$N_0P_0K_0Zn_0$	2.80	8.31	17.1	21.1	3.9	1.23	48.2	0	0	0	0
SEm±	-	0.09	0.12	0.23	0.21	0.16	0.02	7.73	0.53	0.22	2.94	1.70
CD (P=0.05)	-	0.19	0.25	0.48	0.44	0.32	0.05	15.96	1.09	0.46	6.06	3.51

ONT*, Optimum Nutrient Treatment; PFP, Partial factor productivity; AE, Agronomic efficiency; PE, Physiological efficiency; RE, Recovery efficiency

age, about 27.4 kg of maize grain was produced/kg of nitrogen applied in Mayamankuruchi soil series and about 27.1 kg of maize grain was produced/kg of nitrogen applied in Madukkur soil series (Tables 1 and 2). The partial factor productivity was higher as the rate of nitrogen application decreased in both soils. Saradha (2000) explained that the increased levels of N declined the partial factor productivity due to less efficiency on utilization of absorbed nitrogen. Application of blanket recommendation of nitrogen (135 kg/ha) in both soils performed best and maintained the highest partial factor productivity (45.0 and 44.3 kg/kg (N) respectively) than other levels of nitrogen application. The treatments with enhanced levels of P and K with the optimum doses of nitrogen (200 kg/ha) recorded the higher PFP in these two soils. The treatments without P or K registered lower values (18.9 and 19.7 kg/kg (N) respectively) of PFP in Mayamankuruchi soil series. The same trend was observed in Madukkur soil series also (18.7 and 19.6 kg/kg (N), respectively). This indicates that the hybrid maize is more responsive to the optimum dose of nitrogen along with balanced fertilization of P and K for better partial factor productivity.

Agronomic efficiency: The agronomic efficiency represents the product of physiological efficiency (PE) with which the crop utilizes the acquired N to produce more grain and the recovery efficiency (RE) of applied nitrogen (Stalin *et al.*, 1999). The agronomic efficiency ranged from 4.9 to 24.2 and 5.2 to 24.3 kg N/ha in Mayamankuruchi and Madukkur soil series respectively. The treatment received higher levels of NPK with Zn registered the higher values of agronomic efficiency and the lower values obtained from the treatments omitted by N or P or K in both soil series. This implies that the balanced use of nutrients is highly essential for maintaining crop growth and higher agronomic use efficiency. Since the plant growth and N uptake are closely interrelated, it is difficult to determine whether poor AE is due to the inability of the plant to recover N or the inability of the plant to utilize that N for growth and yield production (Craswell and Godwin, 1984). Adoption of inefficient N management practices is responsible for low agronomic efficiency. Agronomic efficiency is a useful measure of nutrient-use efficiency, as it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system (Yadav, 2003).

Physiological efficiency: The physiological efficiency ranged from 45.0–86.3 kg/kg (N) for hybrid maize cultivated in Mayamankuruchi soil series and it was observed from 47.1–94.9 kg/kg (N) in Madukkur soil series (Tables 1 and 2). The highest values of PE were found to the treatments omitted by Zn ($N_2P_2K_2$-Zn) in both soil series. The treatments without nitrogen and potassium registered lower physiological efficiency in both soil series (45.0 and 47.1 kg/kg (N) respectively). Decline in physiological efficiency in both soil was due to nutrient imbalance and decline in indigenous soil N supply. Abdul Rehman *et al.* (2011) reported that nitrogen-utilization efficiency was the highest with low NPK rate followed by the high NPK dose

Table 2. Yield, economics and Nitrogen-use efficiency of maize 'COH M 5' in Madukkur soil series (Alfisol) (mean data of 2 years)

Treatment	Nutrient doses (kg/ha)	Grain yield (tonnes/ ha)	DMP (tonnes/ ha)	Cost of cultivation (×10³₹/ ha)	Gross returns (×10³₹/ ha)	Net returns (×10³₹/ ha)	Benefit: cost ratio	N uptake (kg/ha)	N-use efficiency, kg/kg (N)			
									PFP	AE	PE	RE (%)
$N_0P_2K_2$Zn	$N_0P_{60}K_{25}Zn_{10}$	3.16	9.27	20.9	23.9	3.0	1.14	65.7	0	0	85.0	0
$N_1P_2K_2$Zn	$N_{150}P_{60}K_{25}Zn_{10}$	6.07	16.14	22.5	45.5	22.9	2.02	138.5	40.5	22.5	92.7	59.5
$N_2P_2K_2$Zn (ONT)	$N_{200}P_{60}K_{25}Zn_{10}$	7.21	19.36	23.1	54.1	31.0	2.34	203.6	36.0	22.6	74.4	77.2
$N_3P_2K_2$Zn	$N_{250}P_{60}K_{25}Zn_{10}$	7.91	22.12	23.6	59.5	35.9	2.52	247.5	31.6	20.8	71.9	79.3
$N_2P_0K_2$Zn	$N_{200}P_0K_{25}Zn_{10}$	3.74	11.59	21.3	28.4	7.1	1.33	106.4	18.7	5.2	65.1	28.6
$N_2P_1K_2$Zn	$N_{200}P_{45}K_{25}Zn_{10}$	6.27	16.31	22.6	46.9	24.3	2.07	147.0	31.3	17.8	86.3	48.9
$N_2P_3K_2$Zn	$N_{200}P_{75}K_{25}Zn_{10}$	6.96	18.08	23.5	52.0	28.5	2.21	200.9	34.8	21.3	67.3	75.8
$N_2P_2K_0$Zn	$N_{200}P_{60}K_0Zn_{10}$	3.93	10.73	21.9	29.4	7.5	1.34	109.9	19.6	6.1	47.1	30.3
$N_2P_2K_1$Zn	$N_{200}P_{60}K_{18.75}Zn_{10}$	6.19	15.97	22.8	46.3	23.6	2.04	146.7	31.0	17.5	83.2	48.7
$N_2P_2K_3$Zn	$N_{200}P_{60}K_{31.25}Zn_{10}$	7.09	19.07	23.3	53.2	29.9	2.28	211.9	35.5	22.0	68.9	81.3
$N_2P_2K_2$ -Zn	$N_{200}P_{60}K_{25}$ -Zn_0	5.78	14.93	21.9	43.2	21.3	1.98	123.7	28.9	15.4	94.9	37.2
Blanket	$N_{135}P_{62.5}K_{50}Zn_{5.5}$	5.97	15.34	20.9	44.5	23.6	2.13	130.2	44.3	24.3	92.3	60.0
Control	$N_0P_0K_0Zn_0$	2.70	7.87	17.2	20.4	3.1	1.18	49.2	0	0	0	0
SEm±	-	0.06	0.13	0.16	0.18	0.13	0.02	7.30	0.43	0.20	0.74	0.46
CD (P=0.05)	-	0.13	0.26	0.33	0.38	0.27	0.04	15.06	0.89	0.42	1.52	0.94

ONT*, Optimum Nutrient Treatment; PFP, Partial factor productivity; AE, Agronomic efficiency; PE, Physiological efficiency; RE, Recovery efficiency

(300:150:150 kg NPK/ha) and the lowest efficiency was observed with medium fertilizer dose (250:125:125 kg NPK/ha) in maize. Similar reports were observed by Jain and Sharma (2009) in soybean.

Recovery efficiency: The fraction of applied N that is absorbed by a crop is expressed as apparent N recovery and is calculated as the ratio of actual uptake minus uptake in unfertilized plots, to the applied amount of N. The recovery efficiency ranged from 29.5–85.6 and 28.6–81.3% in Mayamankuruchi and Madukkur soil series respectively (Tables 1 and 2). The lower values of recovery efficiency were recorded by the treatments (omitted by P or K or Zn in both soils. Singandhupe *et al*. (2011) reported that the amount of N recovery efficiency was maximum with increasing nitrogen level in rice. The highest values of recovery efficiency were registered in the treatments received with higher levels of N or P or K in two soils. Cassman *et al.* (2002) reported that the highest fertilizer recovery was obtained by applying 50:15 kg NP/ha and 50:30 kg NP/ha under varying soil conditions. This indicates that applying fertilizer in higher amounts might have resulted in more nutrient losses. Zada *et al.* (2000) reported that nutrient-use efficiency increases with increasing fertilizers rates up to a certain level and then starts declining gradually.

*Nitrogen balance:*Nitrogen balance in terms of net gain or net loss of nitrogen was computed from the nitrogen status of the soil before and after harvest, quantity of nitrogen applied as inorganic sources and the uptake of nitrogen by the crop. The calculated quantity of nitrogen balance was compared with theoretical (measured) balance of nitrogen present in soil. The net nitrogen balance was positive in all the treatments added with nitrogen in Mayamankuruchi soil series (Table 3). The highest available N (256 kg/ha) and the balance (25.7 kg/ha) was recorded with 250:64:48:4.8 kg NPK Zn/ha over initial soil fertility level. With the increase in each level of fertility (N, P and K) also assured the availability of these nutrients to the crop plants in adequate amount and remained in soil in substantial quantity after fulfilling the crop requirement that ultimately improved the soil fertility. It was confirmed by the findings of Saha and Mondal (2006). In Madukkur soil series, the highest available N (181 kg/ha) and the balance (33 kg/ha) was recorded with 250:70:150:9.6 kg NPK Zn/ha over initial soil fertility level. The negative balance of nitrogen was observed in treatments omitted by N or P or K or Zn in Madukkur soil series. The native soil nutrients were low in this soil, which led to poor values in balance of nitrogen. Further, The negative balance of nitrogen in this soil series might be ascribed to the fact that loss of nitrogen. The net negative nitrogen balance registered in this soil was due to more nitrogen uptake by the crop and due to the immobilization of biological processes due to nitrogen transformation (Duhan *et al*. 2005).

Economics: Net returns and benefit: cost ratio was significantly influenced by various levels of fertilization in both soil series. In Mayamankuruchi soil series, net returns

Table 3. Nitrogen balance (kg/ha) after harvest of maize 'COHM5' in Mayamankuruchi and Madukkur soil series (mean data of 2 years)

Treatment	Mayamankuruchi soil series (Inceptisol)				Madhukkur soil series (Alfisol)			
	N applied	N removed (B)	Available N (post harvest) (C)	Actual gain/loss (C-A*)	N applied	N removed (B)	Available N (post harvest) (C)	Actual gain/loss (C-A*)
$N_0P_2K_2Zn$	0	72.5	217	-13.3	0	65.7	131	-17
$N_1P_2K_2Zn$	150	149.9	236	5.7	150	138.5	158	10
$N_2P_2K_2Zn$ (ONT)	200	219.4	244	13.7	200	203.6	167	19
$N_3P_2K_2Zn$	250	260.8	256	25.7	250	247.5	181	33
$N_2P_0K_2Zn$	200	109.6	233	2.7	200	106.4	135	-13
$N_2P_1K_2Zn$	200	160.1	237	6.7	200	147.0	149	1
$N_2P_3K_2Zn$	200	209.3	240	9.7	200	200.9	160	12
$N_2P_2K_0Zn$	200	107.1	231	0.7	200	109.9	134	-14
$N_2P_2K_1Zn$	200	157.6	233	2.7	200	146.7	142	-6
$N_2P_2K_3Zn$	200	211.5	239	8.7	200	211.9	168	20
$N_2P_2K_2$ -Zn	200	113.9	229	-1.3	200	123.7	135	-13
Blanket	135	132.5	231	0.7	135	130.2	145	-3
Control	0	48.2	208	-22.3	0	49.2	116	-32
SEm±	-	7.73	0.64	-	-	7.30	1.58	-
CD (P=0.05)	-	15.96	1.32	-	-	15.06	3.25	-

*Initial Soil N 230.3 kg/ha (A) *Initial Soil N 148 kg/ha (A)

ONT*, Optimum Nutrient Treatment; PFP, Partial factor productivity; AE, Agronomic efficiency; PE, Physiological efficiency; RE, Recovery efficiency

and benefit: cost ratio increased significantly with each successive increase in fertility level and on mean basis, net returns and benefit: cost ratio were highest with application of 250:64:48:4.8 kg NPK Zn/ha. The recommended dose of fertilizer with 135-62.5-50-5.5 kg NPK Zn/ha recorded the net income of ₹24,400/ha with the benefit: cost ratio of 2.16 (Table 1). In Madhukkur soil series, the highest dose of N as 250:64:48:4.8 kg of NPK and Zn/ha had resulted in the net income of ₹35,900/ha with the benefit: cost ratio of 2.52. The blanket recommendation with 135:62.5:50:5.5 kg of NPK and Zn/ha recorded the net income of ₹23,600/ha with the benefit: cost ratio of 2.13 (Table 2).

Based on the study, it was concluded that to get better N-use efficiency, maximum productivity and highest net return from maize 'COHM 5' in Inceptisols and Alfisols of Tamil Nadu, the crop should be fertilized with 250:64:48:4.8 and 250:70:150:9.6 kg of NPK and Zn /ha, respectively.

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