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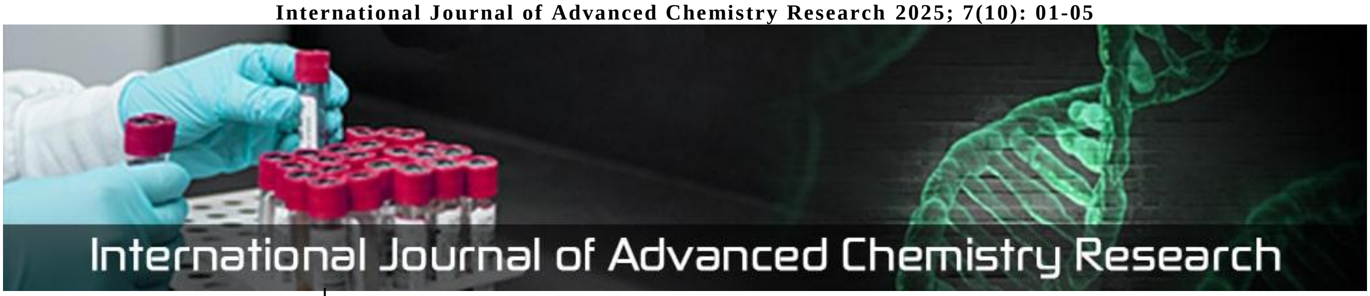

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Dynamics of nitrogen and mineralization pattern in modified Amrashakti

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Abstract

An experiment entitled “Dynamics of nitrogen and Mineralization Pattern in Modified Amrashakti” was undertaken at Department of soil science and agricultural chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri during 2024-25 in Randomized Block Design. This study aimed to evaluate the nutrient stability and mineralization behaviour of nitrogen fractions (amide nitrogen, ammoniacal nitrogen and nitrate nitrogen) in modified Amrashakti Multinutrient solution during six months of storage. Three solutions *viz*., T_1 @ 0.5% (Urea, SOP, SSP each) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate), T_2 @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate) and T_3 @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate) with varying pH levels were formulated using different NPK and micronutrient sources. Monthly analysis of nitrogen (amide, ammoniacal, nitrate) by standardised methodology. Based on the mineralization behavior and nutrient fractionation observed over the six-month storage period. Solution T_2 consistently outperformed T_1 and T_3 in terms of nutrient stability, solubility, and availability. T_2 maintained higher levels of available nitrogen (through balanced amide to nitrate conversion), Minimal precipitation and better compatibility of nutrient sources in T_2 contributed to its superior performance. Decline in amide nitrogen, ammoniacal nitrogen and nitrate nitrogen in solutions were observed in second month. Therefore, it may be concluded that Solution T_2 is the most effective formulation among the three, particularly in maintaining nutrient availability and solution stability, and is best recommended for use within two months of preparation for optimal efficiency. Results indicated a decline in pH and EC, accompanied by nutrient losses over time. T_2 with acidic pH, showed better nutrient stability and solubility, while T_1 recorded greater precipitation and nutrient decline. The findings suggest that the modified Amrashakti Multinutrient solution (T_2) i.e., @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate) might be most effective within two months of preparation, beyond which nutrient degradation may impact efficacy.

Keywords: Amrashakti, foliar fertilizer, nutrient dynamics, mineralization, shelf life, mango

Introduction

Mango (*Mangifera indica* L.), the “King of Fruits,” is one of the most important fruit crops of India, contributing significantly to export earnings and the horticultural economy of the Konkan region. Alphonso mango, predominantly grown in Ratnagiri, Sindhudurg, and Raigad districts, has unique flavour and quality but suffers from low and inconsistent productivity. Among several limiting factors, nutrient deficiencies particularly of nitrogen, phosphorus, potassium, zinc, and copper are most critical. Conventional soil application often fails to meet crop requirements due to leaching losses, fixation in lateritic soils, and low nutrient use efficiency. Consequently, foliar nutrition has emerged as a practical alternative for supplementing plant nutrient needs efficiently.

Amrashakti, a Multinutrient foliar spray developed by DBSKKV, Dapoli, has demonstrated positive effects on mango productivity by supplying balanced nutrition in one formulation. The Old formulation (T_1) i.e. @ 0.5% (Urea, SOP, SSP each) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate) formulated by Patil *et al.* (2010) [4]A However, precipitation of salts due to incompatibility between SSP and micronutrient sources often led to nozzle clogging, reduced nutrient solubility, and limited shelf life. To overcome these challenges, Modified formulations were developed by Patil *et al.* (2023) [5] where T_2 replaced single super phosphate (SSP) with orthophosphoric acid, while T_3 combined calcium nitrate and potassium nitrate with phosphoric acid. These changes aimed at improving solubility, minimizing precipitation, and enhancing nutrient stability during storage.

Although Amrashakti has been widely used by mango growers, systematic studies on its nutrient dynamics and mineralization behavior under storage conditions were lacking. Therefore, the present study was undertaken to evaluate nutrient fractionation and mineralization patterns in Old and Modified Amrashakti formulations over six months of storage.

Materials and Methods

The study was carried out at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, DBSKKV, Dapoli, from January to June 2025. The experiment comprised three treatments:

- **T_1:** Old Amrashakti @ 0.5% (Urea, SOP, SSP each) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)
- **T_2:** Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)
- **T_3:** Modified formulation E@ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)

Each treatment was replicated seven times in a Randomized Block Design. One-liter solutions were prepared and stored in plastic bottles under ambient room temperature. A total of 126 bottles were prepared (42 per treatment). At monthly intervals, samples were collected for chemical analysis over six months.

Parameters studied included: pH, electrical conductivity (EC), amide nitrogen, ammoniacal nitrogen, nitrate nitrogen, Nitrogen fractions were determined by micro-Kjeldahl method, pH and EC were recorded using digital meters. Statistical analysis was carried out using RBD design to determine treatment and storage duration effects

Methods

Standardization of analytical procedure

For nitrogen, the analytical procedure was standardized to measure its different forms ammoniacal, nitrate, and amide nitrogen in the liquid fertilizer. Ammoniacal nitrogen was estimated by distillation after treating the sample with alkali, while nitrate nitrogen was determined by using Devarda's alloy method. Urea (amide nitrogen) was estimated after hydrolysis to ammoniacal form followed by distillation. These methods were tested repeatedly to check accuracy and reproducibility, and the most consistent procedure was finalized. Standardization was important because even small errors could affect the results of nutrient stability and mineralization studies. The finalized procedure ensured reliable measurement of nitrogen fractions during storage, providing a strong base for assessing the nutrient dynamics and shelf life of the modified Amrashakti formulations.

Fractions of Nitrogen

1) Ammoniacal nitrogen

The ammoniacal nitrogen content was determined by distillation titrimetric method. released ammonia from the digested sample collected in 4 % boric acid in the Kjeldahl plus apparatus and titrate with 0.1*N* std. H_2SO_4 (Indian standard method of sampling and test for fertiliser (Part 2), 1985).

2) Nitrate nitrogen

The nitrate nitrogen content was determined by Devarda's alloy reduction method. The released ammonia from the digested sample collected in 4 % boric acid in the Kjeldahl plus apparatus and titrate with 0.1*N* Std. H_2SO_4 (Indian standard method of sampling and test for fertiliser (Part 2), 1985).

3) Amide nitrogen

The amide nitrogen content was determined by distillation titrimetric method. The released ammonia from the digested sample collected in 0.1*N* H_2SO_4 in the Kjeldahl plus apparatus and titrate with 0.1*N* Std. NaOH. (Laboratory Manual in Agricultural Chemistry, 1965).

Results and discussion

pH

The data pertaining to pH of different Amrashakti Multinutrient solutions prepared in the present research indicated that Old Amrashakti Multinutrient solution (T_1) noted the pH value of 5.21 in January, 5.10 in February, 5.32 in March, 5.48 in April, 5.29 in May and 5.36 in June; Modified Amrashakti Multinutrient solution (T_2) noted the pH value of 2.41 in January, 1.79 in February, 2.61 in March, 2.07 in April, 2.53 in May and 3.81 in June and Modified Amrashakti Multinutrient solution (T_3) noted the pH value of 1.84 in January, 1.12 in February, 1.76 in March, 1.07 in April, 1.64 in May and 1.70 in June.

The close scrutiny of data indicated that decline in pH of all the Amrashakti Multinutrient solutions over time can be attributed to the fact that urea can hydrolyse to ammonium carbonate, which can later dissociate, forming CO_2 and H^+ ions, thus lowering pH. Over time, continuous dissociation of orthophosphoric acid increases free hydrogen ion (H^+) concentration, lowering pH further. Micronutrients like Cu^{2+}, Zn^{2+} and B^{3+} can precipitate or form complexes, disrupting buffering and contributing to acidification. Again, none of the solutions seem to have strong pH buffers (e.g., citrates or carbonates), allowing pH to shift more easily.

Table 1: Periodical changes of pH in Amrashakti Multinutrient solutions

Treatment		January	February	March	April	May	June
T_1	Old Amrashakti @ 0.5% (Urea, SOP, SSP, each) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)	5.21	5.10	5.32	5.48	5.29	5.36
T_2	Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	2.41	1.79	2.61	2.07	2.53	3.81
T_3	Modified Amrashakti @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	1.84	1.12	1.76	1.07	1.64	1.70
S.E. (m) ±		0.01	0.004	0.14	0.02	0.02	0.35
CD@ 0.05		0.03	0.013	0.44	0.05	0.06	1.08

Electrical Conductivity (EC)

The electrical conductivity of different Amrashakti Multinutrient solutions showed that Old Amrashakti Multinutrient solution (T_1) noted the EC value of 62.02 dSm^{-1} in January, 51.07 dSm^{-1} in February, 54.83 dSm^{-1} in March, 55.73 dSm^{-1} in April, 51.14 dSm^{-1} in May and 44.31 dSm^{-1} in June; Modified Amrashakti Multinutrient solution (T_2) noted the EC value of 63.61 dSm^{-1} in January, 54.33 dSm^{-1} in February, 56.26 dSm^{-1} in March, 57.74 dSm^{-1} in April, 54.56 dSm^{-1} in May and 47.71dS m^{-1} in June and Modified Amrashakti Multinutrient solution (T_3) noted the EC value of 107.13 dSm^{-1} in January, 91.03 dSm^{-1} in February, 98.00 dSm^{-1} in March, 97.57 dSm^{-1} in April, 93.81 dSm^{-1} in May and 84.57 dSm^{-1} in June (Table 4.2).

The decline in electrical conductivity (EC) of the three foliar fertilizer solutions over a six-month storage period might be due to chemical precipitation, degradation, and reduced solubility of nutrients with time. Elements like Ca^{2+}, PO_4^{3-}, Cu^{2+}, Zn^{2+}, and B^{3+} can form insoluble compounds (e.g., calcium phosphate, copper phosphate), especially in concentrated or acidic solutions. Once precipitated, these ions no longer contribute to EC. Urea hydrolysis and nitrate volatilization can alter ion balance. Over time, lower pH increases solubility for some micronutrients but also promotes complexation of others, reducing free ions in solution. Further, exposure to light, heat, and air can accelerate chemical reactions leading to ion binding or loss.

Amide Nitrogen (NH_2–N)

T_3 registered the higher values of amide form in the month of January (0.72%), which declined onward rapidly due to highly acidic pH as low pH (1.07 to 1.84) accelerates amide degradation.

In Modified Amrashakti Multinutrient solution (T2), amide nitrogen was lowest in January (0.44%) due to the acidic environment created by phosphoric acid, which promoted hydrolysis of urea. A peak value (2.07%) was observed in February, indicating intact urea before its rapid degradation under acidic pH. From March to June, Old Amrashakti (T_1) maintained higher amide nitrogen levels owing to its moderate pH, which favoured urea stability and reduced hydrolysis.

Urea generally hydrolyses through urease activity into ammonium (NH_4^+) and CO_2, but under acidic laboratory conditions this activity is inhibited. Therefore, thermal hydrolysis using sulfuric acid digestion was employed to convert urea into ammoniacal nitrogen. As explained by Meessen (2010) [2], heating urea in acidic aqueous media releases ammonia and isocyanic acid, which further react to produce ammonium and CO_2.

$CO(NH_2)_2 + H_2O + \text{heat} \rightarrow 2NH_4^+ + CO_2\uparrow$

Table 2: Periodical changes of EC (dSm^{-1}) in Amrashakti Multinutrient solutions

Treatment		January	February	March	April	May	June
T_1	Old Amrashakti @ 0.5% (Urea, SOP, SSP, each) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)	62.02	51.07	54.83	55.73	51.14	44.31
T_2	Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	63.61	54.33	56.26	57.74	54.56	47.71
T_3	Modified Amrashakti @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	107.13	91.03	98.00	97.57	93.81	84.57
S.E. (m) ±		0.19	0.22	0.49	0.48	0.14	0.12
CD@ 0.05		0.60	0.67	1.51	1.46	0.44	0.36

The significantly highest values of ammoniacal nitrogen were observed in Modified Amrashakti Multinutrient solution (T_2) constantly in all months, where this solution (T_2) was found to be significantly superior over other two solutions in the month of January and June, while at par with Old Amrashakti Multinutrient solution (T_1) in the month of February, March, April and May. The lowest values of ammoniacal nitrogen were observed in Modified Amrashakti Multinutrient solution (T_3). The highest values of ammoniacal nitrogen in Modified Amrashakti Multinutrient solution (T_2) ascribed to the contains urea in solution, which hydrolyses faster in acidic conditions. Further, presence of phosphoric acid (low pH) accelerates urea hydrolysis, producing ammonium (NH_4^+) and CO_2.

The lowest amount of ammoniacal nitrogen in Modified Amrashakti Multinutrient solution (T_3) since no urea present in the solution and the main nitrogen sources are calcium nitrate, potassium nitrate and ammonium molybdate, which provide nitrate (NO_3^-) and very less amount of ammoniacal nitrogen. Moreover, the low pH and absence of amide N prevent any significant formation of ammoniacal N. Therefore, it records the lowest ammoniacal N values.

The correlation between rising amide nitrogen and the early peak in ammoniacal nitrogen suggests that thermal hydrolysis occurred in the initial stage (in January). Subsequently, both forms of nitrogen appeared to reach a state of dynamic equilibrium, particularly from march onwards. This equilibrium is likely a result of the balance between continuous but slow conversion of amide nitrogen and the stabilization of ammoniacal nitrogen concentration might be due to saturation or limited conversion beyond a threshold. As also demonstrated by Meessen (2010) [2], who reported that urea decomposition under acidic and thermal conditions leads to the formation of ammoniacal nitrogen.

Table 3: Periodical changes of Amide Nitrogen (NH_2^+-N) % in Amrashakti Multinutrient solution

Treatment		January	February	March	April	May	June
T_1	Old Amrashakti @ 0.5% (Urea, SOP, SSP, each) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)	0.52	1.86	2.01	2.20	1.52	0.92
T_2	Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) + 0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	0.44	2.07	0.72	0.56	0.52	0.44
T_3	Modified Amrashakti @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	0.72	0.60	-1.80	-0.48	0.40	0.40
S.E. (m) ±		0.06	0.19	0.11	0.09	0.10	0.11
CD@ 0.05		0.19	0.59	0.35	0.29	0.31	0.33

Nitrate Nitrogen (NO_3^-–N)

Urea was used in Old Amrashakti Multinutrient solution (T_1) and Modified Amrashakti Multinutrient solution (T_2), which provides amide nitrogen (NH_2). Urea does not contain nitrate and must undergo enzymatic hydrolysis (in soil or in biological systems) to eventually form ammonium (NH_4^+) and then nitrate (NO_3^-) through nitrification. Besides this, in liquid form (without microbial activity), urea does not convert to nitrate on its own. However, in Modified Amrashakti Multinutrient solution (T_3) contains calcium nitrate which directly supplies Ca^{2+} and NO_3^- and potassium nitrate which directly supplies K^+ and NO_3^-. These are fully dissociating salts, and they immediately release nitrate ions (NO_3^-) into the solution.

The decline in nitrate nitrogen content in Modified Amrashakti Multinutrient solution (T_3) from 3.69% in January to 0.72% in June is likely due to several chemical and environmental factors that affect nitrate stability in stored aqueous fertilizer solutions. Although nitrate itself is stable, under acidic conditions, it can undergo chemical reduction or participate in slow denitrification-like reactions (especially if any microbial contamination occurs). Over time, nitrate may volatilize or convert to gases like nitric oxide (NO), nitrous oxide (N_2O), or nitrogen gas (N_2) especially in closed or semi-aerated storage.

This observation aligns with the findings of Filimonov and Shcherbakov (2004) [3], who reported that in acidic phosphoric acid solutions, cuprous ions (Cu^+) formed through copper redox cycling can chemically reduce nitrate ions (NO_3^-) to nitric oxide (NO). The resulting NO, being electroactive, undergoes further reduction more readily at the cathode, thus enhancing the overall nitrate reduction pathway. These findings suggest that under the acidic conditions present in Treatment T_3, copper may have acted as a catalytic agent facilitating the reduction of nitrate, contributing to the observed decline in its concentration.

Shelf Life of Amrashakti Multinutrient solution

In present investigation the shelf life of Old and modified Amrashakti formulations (T_1, T_2 and T_3) were observed for a period of six months from January 2025 to June 2025.

The results indicated that all three solutions exhibited noticeable changes in the nutrient fractions and chemical properties, especially from the second month of storage. A decline in the pH and electrical conductivity (EC) was observed during February across all treatments. Simultaneously, the nitrogen fractions decreased significantly.

Among the three solutions, Solution T_2 maintained comparatively higher nutrient values of amide nitrogen, ammoniacal nitrogen and nitrate nitrogen throughout the study period, followed by Solution T_3. These findings are in accordance with the results reported by Patil *et al.* (2023) [5].

Table 4: Periodical changes of Ammoniacal nitrogen (NH_4^+) % in Amrashakti Multinutrient solution

Treatment		January	February	March	April	May	June
T_1	Old Amrashakti @ 0.5% (Urea, SOP, SSP, each) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)	3.86	2.50	2.31	2.10	2.19	2.38
T_2	Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	5.41	2.53	2.38	2.33	2.39	2.49
T_3	Modified Amrashakti @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	0.79	0.47	0.50	0.82	0.81	0.77
S.E. (m) ±		0.13	0.02	0.04	0.02	0.04	0.03
CD@ 0.05		0.41	0.07	0.11	0.07	0.12	0.08

However, Treatment T_2, although it exhibited a decline in nutrient content from the second month, showed promising initial results with negligible precipitation, which could have positively influenced nutrient availability. In contrast, Treatment T_1 exhibited high solubility issues leading to precipitate formation, which could have decreased the nutrient content in the liquid fertiliser. Similarly, Treatment T_3 also showed half of the precipitation as compared to T_1, which may also have led to nutrient suppression and reduced uniformity during application. The precipitation in treatment T_1 could have possibly influenced by the use of SSP single super phosphate) along with SOP (sulphate of potash)

Thus, considering both nutrient stability and physical behavior (solubility and precipitation), it is recommended that the Amrashakti Multinutrient solution be used within two months of preparation. Beyond this period, significant changes in nutrient composition and physical properties may compromise its effectiveness and applicability.

Conclusion

Based on the mineralization pattern and fractionation study of the modified Amrashakti Multinutrient Solution, it may be inferred that the solution undergoes noticeable changes in nutrient stability and solubility over a six-month storage period. The observed decline in pH and EC from February onwards suggests a shift in chemical equilibrium, possibly due to transformations among nitrogen fractions

The mineralization behavior of nitrogen revealed a conversion of amide to ammoniacal and subsequently to nitrate forms, influenced by treatment composition and pH. Treatment T_2 demonstrated a balanced transformation pattern with minimal losses, while T_1 exhibited greater instability due to solubility issues and higher precipitation.

Based on the mineralization behavior and nutrient fractionation observed over the six-month storage period, Treatment T_2 consistently outperformed T_1 and T_3 in terms of nutrient stability, solubility, and availability. T_2 maintained higher levels of available nitrogen (through balanced amide to nitrate conversion) along with Minimal precipitation and better compatibility of nutrient sources in T_2 contributed to its superior performance. Therefore, it may be concluded that Treatment T_2 is the most effective formulation among the three, particularly in maintaining nutrient availability and solution stability, and is best recommended for use within two months of preparation for optimal efficiency

Table 5: Periodical changes of Nitrate nitrogen (NO_3^--N) % in Amrashakti Multinutrient solution

Treatment		January	February	March	April	May	June
T_1	Old Amrashakti @ 0.5% (Urea, SOP, SSP, each) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.01% (sodium molybdate)	- 3.07	- 2.62	- 2.19	- 1.08	- 2.51	- 2.51
T_2	Modified Amrashakti @ 0.5% (Urea, SOP, each) + 0.15% (Orthophosphate Phosphoric acid) +0.25 % ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	- 4.70	- 2.01	- 2.17	- 2.03	- 2.18	- 2.18
T_3	Modified Amrashakti @ 1% (calcium nitrate) + 0.1% (phosphoric acid) + 0.55% (potassium nitrate) + 0.25% ($ZnSO_4$, Borax, $CuSO_4$ each) + 0.0075% (Ammonium molybdate)	3.69	2.68	1.82	1.79	1.78	0.72
S.E. (m) ±		0.31	0.62	0.13	0.17	0.17	0.17
CD@ 0.05		0.95	1.92	0.39	0.52	0.53	0.53

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