

SYNTHESIS AND CHARACTERIZATION OF A NEW GRADE(N-P-K) FERTILIZER FORTIFIED WITH HEPTA-MICRONUTRIENT MATRIX FOR SUPERIOR PLANT GROWTH

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ABSTRACT

An evolving approach to agricultural innovations and effective farming practices are key issues of modern agriculture. New-graded fertilizers have an important role in the present agricultural yield advances. Without the application of fertilizers, the soil would be exhausted and it affects the growth of plants. Micro-nutrients are essential for various plant growth and development processes such as protein synthesis, fruiting, flowering etc. Herein we describe a new N-P-K fertilizer fortified with seven micronutrient matrixes. The author synthesized a 100% water soluble 14-14-14 graded fertilizer with seven micronutrients (14-14-14 with 0.5% Zinc, Manganese, Iron, magnesium, & copper, 0.2% Molybdenum & Boron). The proposed fertilizer was analyzed by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The higher chloride content in either soil or fertilizer leads to less crop yield. The proposed fertilizer chloride content is less than the existing different grades of fertilizers available in the market. The physical properties such as percentage of moisture, pH, conductivity, and critical relative humidity were determined and these properties showed better results as compared to other graded fertilizers.

Keywords: N-P-K Fertilizer, 100% Water Soluble Fertilizer, Micronutrient Matrix, Critical Relative Humidity, ICP-OES.

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INTRODUCTION

Agriculture must grow significantly to meet the global 2050 food demand. The majority of the agriculture plans depend on the employment of chemical fertilizers due to a rise in land scarcity and water shortage.¹ Fertilizers/mineral fertilizers feed the nutrients that are absorbed by the crops from the soil. Mineral fertilizers are quickly absorbed and used by crops. To attain the normal growth and development of plants mineral fertilizers with nutrient support are manufactured. The macronutrients applied in large quantities are Nitrogen, Phosphorus and Potassium(N-P-K). Other elements are required in small or trace quantities and are termed micronutrients. For an increase in crop production to feed the rising human population mineral fertilizers are required. At present the application of fertilizers at the global level was in an unbalanced state. The use of N-P-K fertilizer for decades may have induced micronutrient deficiency and soil deterioration.² Eutrophication occurs due to the absorption of mineral forms of nitrogen by plants and leaching out of the soil into groundwater. Several studies reveal fifty percent of Nitrogen fertilizer applied globally is not utilized by plants.³ Excess application of Nitrogen did not increase yield under dry conditions but rather increased the Nitrogen losses.⁴ A demur in crop yields and soil fertility was observed due to the overuse of chemical fertilizers.⁵ Fertilizers are contributing 20-30% of the total cost of crop production.⁶ Fertiliser use among smallholder farmers is not adequate due to an escalating cost.⁷

Foliar Application of Water-Soluble Fertilizer (WSF)

Foliar fertilization was considered an apt substitute to meet plant nutrient demand and also to overcome plant nutrient insufficiency.⁸ Foliar fertilizers or water-soluble fertilizers are completely soluble in water and needed nutrients are fast delivered to plants in the form of foliar fertilization during the growing season. Both macro and micronutrients can be delivered to plants by foliar fertilization.⁹ WSF is applied in the form of Foliar spray, fertigation, hydroponics and drip irrigation etc. More flowers were possible through foliar application in addition to the application of macronutrients.¹⁰ The application of five foliar

sprays of WSFs appreciably increased the various factors like the height of, number of branches, average fruit weight and its quantity, fruit length and fruit diameter.¹¹⁻¹² The advantages of Foliar application are the rapid and competent deployment of nutrients, purging of losses through leaching, fixation and regulating the uptake of nutrients by plants.¹³ Foliar application of N is more appropriate than soil application because it allows for rapid and efficient transportation of N to the grain.¹⁴ Many researchers have proved that drip irrigation systems are more useful than conventional methods of basic irrigation systems in fruits. Fertilizers applied through drip irrigation improve crop yield and save labour.¹⁵ The application of inorganic fertilizers can be reduced up to 15% with the application of foliar grade water soluble fertilizer.¹⁶ Foliar application of water-soluble fertilizers may be a very good option to augment the yield of pulse crops under the reduced cost of cultivation. The foliar spray technique helps reduce the requirement for fertilizers and their minimization.¹⁷ The application of nutrients through fertigation resulted in higher total nutrient uptake (NPK) than surface irrigation with conventional fertilizer.¹⁸⁻¹⁹ The nutrient enters first into the cuticle or enters through the stomata before entering the plant cell where they can be used in metabolism.²⁰

Micronutrient Role

The foliar application of micronutrients has an energetic role to play in vegetable production.²¹ Iron, Boron, Molybdenum, Zinc, Copper, Magnesium, and Manganese are considered micronutrients. Iron improves the performance of photosystems and plant growth & development. Iron releases energy from sugars and starches in the oxidation process and in responses that convert nitrate to ammonium in plants.²² Deficiency of boron can cause a reduction in crop yield and, impair crop quality.²³ Manganese has an important role in plants and the foliar application or seed treatment of manganese is essential for better crop yield and quality.²⁴ Zinc deficiency symptoms appear in 2 to 3 weeks after transplantation and affect the functioning of nitrate reductase.²⁵ Zinc is the most deficient nutrient in Indian soils, followed by Boron. Initially, the incidence of Zn deficiency was observed more in cereals, particularly rice and wheat belts of the country, but with time, the distribution of Zn deficiency has covered the whole country across the crops and cropping systems.²⁶ Molybdenum forms the essential component of nitrate reductase enzyme and nitrogenase, thus required for Nitrogen metabolism. Molybdenum promotes the fixation of nitrogen and also improves the Phosphorus uptake by plants.²⁷ Magnesium deficiency and sugar accumulation in the leaves causes feedback inhibition of Rubisco and lowers the rate of photosynthesis and also cause oxidative stress.²⁸ Copper deficiency-derived signals lead to a delay in flowering time and senescence. Copper enhances flavour and colour in vegetables and flowers²⁹ and its deficiency can change the essential functions in plant metabolism.³⁰

EXPERIMENTAL

Material and Methods

A 100% WSF with seven micronutrients (14-14-14-3S with 0.5% Zinc, Manganese, Iron, Magnesium, & copper, 0.2% Molybdenum & Boron) was prepared and tested. The raw materials used for the study are given below.

Table-1: Raw Materials Used for the Study

S. No.	Materials
1	Ammonium sulphate (AS)
2	Mono ammonium phosphate (100% water soluble) (MAP)
3	Urea
4	Potassium nitrate
5	Chelated Zinc
6	Ferrous sulphate
7	Magnesium sulphate
8	Manganese sulphate
9	Ammonium molybdate
10	Copper sulphate pentahydrate
11	disodium octa borate tetrahydrate

The above raw materials were analyzed (Table-2) by using standard methods and based on the analysis final product was prepared. All the instruments (Table-3) used for the analysis are properly calibrated and all the standard solutions were standardized.

Table-2: The Analysis Results of the Raw Materials

Material	Parameter	Result
(NH ₄) ₂ SO ₄	%N	20.2
	%SO ₄ - S	23.2
NH ₄ H ₂ PO ₄	%N	11.5
	% water soluble Phosphorous as P	60.2
Urea	%N	46.1
KNO ₃	% water soluble potassium as K ₂ O	44.5
	% N	12.5
Zn EDTA	%Zn	12.1
MnSO ₄ . H ₂ O	%Mn	30.5
FeSO ₄ . 7H ₂ O	%Fe	19.3
MgSO ₄ .6H ₂ O	%Mg	9.6
(NH ₄) ₆ Mo ₇ O ₂₄ . 4H ₂ O	%Mo	52
CuSO ₄ . 5H ₂ O	%Cu	24
Na ₂ B ₈ O ₁₃ .4H ₂ O	%B	20

Table-3: Instrumentation

Instrument	Make	Model	Purpose
ICP –OES	Perkin Elmer	Optima 7000DV	To check Mn, Cu, B and Mo
Segmented flow analyzer	Skalar	SAN++	To check N, P
Hot air oven	Tempo	TI 175	For gravimetric drying
Weighing balance	Sartorius	BSA 225, BSA3202	For weighing

Preparation of 14-14-14 Grade Fertilizer

All the raw materials are grounded to fine powder individually and dried. After drying the materials are stored in polythene bottles to avoid moisture penetration. Triplicate mixtures were prepared by taking the weights of components as shown in Table-4.

Table-4: Weights of Material Taken for Preparation

Material	Raw material requirement for 100gm
Zn EDTA	4.17
disodium octa borate tetrahydrate	1.00
Manganese sulphate	1.64
Copper sulphate Penta hydrate	2.08
Ferrous sulphate	2.63
Magnesium sulphate	5.21
Ammonium molybdate	0.38
MAP	23.33
KNO ₃	31.46
Urea	8.35
Ammonium Sulphate	19.75

All the quantities are mixed properly and grounded finely in the mixer by applying 8000rpm. Prepared mixtures are dried to remove surface moisture gained in the preparation. The formed fortified 14-14-14 grade (N-P-K) with seven micro- nutrients was shown in Fig-1



Fig.-1: 14-14-14 Grade (N-P-K) with Seven Micronutrients

RESULTS AND DISCUSSION

The final product samples were analysed, and the results are shown in the tables.

Table-5: Nutrients Content

Test Parameter	Specification	Trail-1	Trail-2	Reference method
Total Nitrogen % by weight	>14	14.2	14.1	FCO 1985
Nitrate nitrogen % by weight	>3.9	4	3.9	FCO 1985
Ammoniacal nitrogen % by weight	>6.3	6.4	6.3	segmented flow analysis
Urea Nitrogen % by weight	<3.8	3.83	3.9	segmented flow analysis
Water Soluble phosphate (as P ₂ O ₅) % by weight	>14	14.2	14.2	segmented flow analysis
Water soluble potash (as K ₂ O) % by weight	>14	14.2	14.1	FCO 1985
Sulphate sulphur (as S) % by weight	>3.0	3.2	3.2	FCO 1985
Zinc as Zn % by weight	>0.5	0.5	0.53	AOAC method for fertilizers
Iron as Fe % by weight	>0.5	0.51	0.51	AOAC method for fertilizers
Magnesium as Mg % by weight	>0.5	0.49	0.52	AOAC method for fertilizers
manganese as Mn % by weight	>0.5	0.53	0.49	AOAC method for fertilizers
Molybdenum as Mo % by weight	0.2-0.3	0.19	0.2	AOAC method for fertilizers
Copper as Cu % by weight	>0.5	0.52	0.5	AOAC method for fertilizers
Boron as B % by weight	0.2-0.3	0.22	0.2	AOAC method for fertilizers

Table-6: Impurities

Test parameter	Specification	Trail-1	Trail-2	Reference method
Arsenic as As, ppm by weight	<100	3.6	4.5	AOAC method for fertilizers
Lead as pb, ppm by weight	<30	<1	1	AOAC method for fertilizers
Cadmium as Cd, ppm by weight	<25	<1	1	AOAC method for fertilizers
Total chlorides as Cl % by weight	<1.5	0.21	0.24	FCO 1985
Sodium as NaCl % by weight	<0.5	0.15	0.17	FCO 1985
Matter insoluble in water % by weight	<0.5	0.31	0.34	FCO 1985

Calibration Graphs on Segmented Flow Analyzer

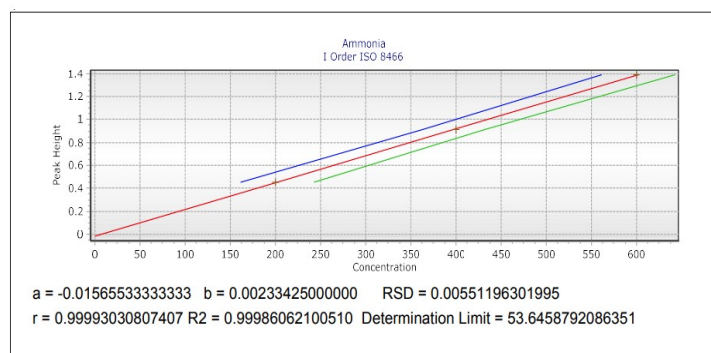


Fig.-2: Calibration Graph-Ammoniacal Nitrogen on Auto Analyser

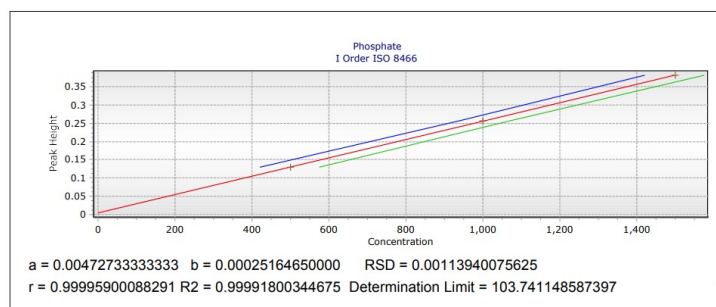


Fig.-3: Calibration Graph- Phosphate on Auto Analyser

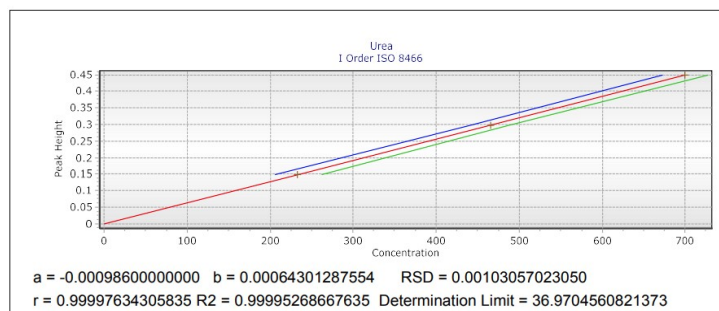


Fig.-4: Calibration Graph- Urea Nitrogen on Auto Analyser

Table-7: Physical Properties

Test Parameter	Specification	Trail-1	Trail-2	Reference method
moisture % by weight	<1	0.28	0.3	FCO 1985
pH of 5% solution	-	4.7	4.6	FCO 1985
Conductivity, ms/cm	-	16.8	16.7	FCO 1985
%Critical relative humidity	-	68	70	IFDC procedure

Determination of Physical Properties of The Proposed Fertilizer

Parameters Selected

The percentage of moisture, pH, conductivity, and critical relative humidity were determined and the results were shown in Table-8.

Table-8: Physical Properties of (14-14-14) NPK Fertilizer with Hepta Micronutrient Matrix

Test Parameter	Trail-1	Trail-2	Reference method
Moisture % by weight	0.28	0.3	FCO 1985
pH of 5% solution	4.7	4.6	FCO 1985
Conductivity, ms/cm	16.8	16.7	FCO 1985
% Critical relative humidity	68	70	IFDC procedure

Importance of Physical Properties

Moisture

Moisture penetration into the fertilizer is a common problem as it is due to the hygroscopic nature of the material. High-nutrient fertilizers absorb moisture more rapidly. Moisture absorption happens in the process of packing and storage which leads to handling problems i.e., caking, lumps formation, and reduction in flowability. In the proposed fertilizer moisture content is very less compared with existing available reputed products like 28-28-0 and 19-19-19. The comparison is shown in Fig.-5.

Critical Relative Humidity (CRH)

Each fertilizer has a CRH and at this point, the fertilizer starts absorbing moisture from the atmosphere which leads to caking phenomena. So if the material has higher CRH, then it forms less caking can cause safety concerns due to the formation of hard and big lumps. uniform application is not possible due to the formation of caking and lumps. In the proposed fertilizer CRH value is high when compared with existing

products available in the markets-28-28-0 and 19-19-19. Moisture absorption was reduced by the addition of anhydrous MgSO_4 .



Fig.-5: moisture Comparison Between Proposed vs Existing Available 100% WSFs

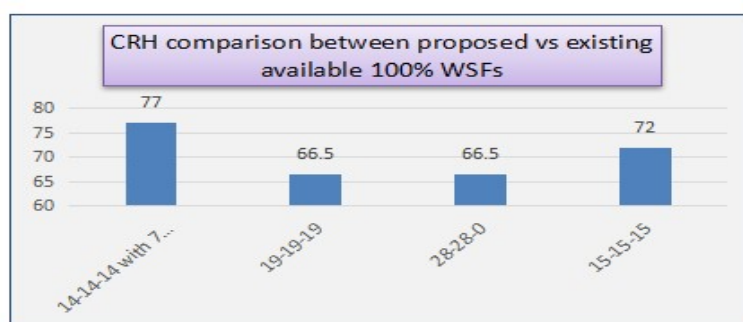


Fig.-6: CRH Comparison Between Proposed vs Existing Available 100% WSFs

Determination of Chloride Content

Chloride content toxicity in plants includes necrosis of leaf margins and tips, which typically occur in old leaves. excessive leaf burn might eventually result in leaf drop. Chloride content in the soil also reduces the ability of the plants to take up water and this results in leaf burn or drying of leaf tissues. Generally, leaf tips are affected first and then severity increases along the leaf. The higher chloride content in either soil or fertilizer leads to less crop yield. The proposed fertilizer chloride content is less than the fertilizers available in the market.

pH

The pH range of 5.5 to 6.5 is ideal for plant nutrients. Aluminium may become toxic to plant growth in certain types of soils with a pH below 5.0. Soil may contain adequate nutrients, yet growth may be limited by a very unfavorable pH. When compared with branded fertilizers available in the market, the proposed fertilizer pH is slightly high which reduces toxicity to the plants. The proposed fertilizer is superior with 4.6 to 4.7 when compared with fertilizers with 3.6 to 4.0 which are available in the market.

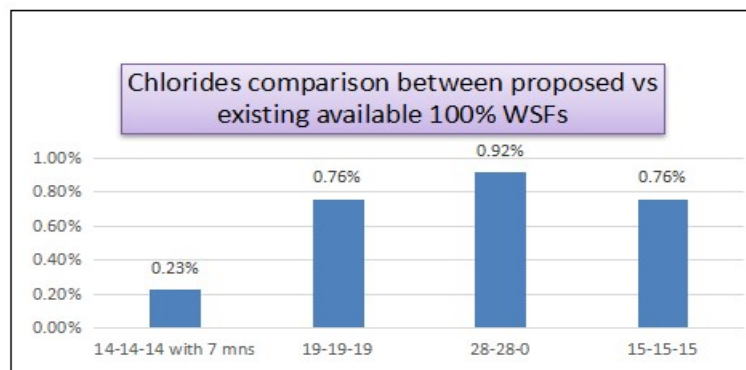


Fig.-7: Chloride Content Comparison Between Proposed vs Existing Available 100% WSFs

CONCLUSION

Micronutrients certainly promote plant growth and its process. The key feature of power-rich fertilizer is the performance of micronutrients in it. The higher chloride content in either soil or fertilizer leads to less crop yield. The proposed fertilizer chloride content is less than the existing different grades of fertilizers available in the market. The proposed 14-14-14 grade (N-P-K) fertilizer fortified with a hepta-micronutrient matrix showed better physical properties when compared to available branded fertilizers.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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