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Preliminary DRIS Norms for Evaluating the Nutritional Status for Rice Crop

Saied El Sayed
National Research Centre
Elham A. Badr
elhamnrc@yahoo.com
National Research Centre
Hanan H. Abdel Kader
National Research Centre

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Abstract

Purpose

Accurate evaluation of plant nutritional status is essential for improving fertilizer management and enhancing rice productivity. Despite the economic importance of rice (*Oryza sativa L.)* in Egypt, locally developed Diagnosis and Recommendation Integrated System (DRIS) norms are still unavailable. Therefore, this study aimed to establish preliminary **DRIS** norms for rice cultivated under Egyptian conditions and to identify nutrient relationships associated with variations in grain yield.

Methods

Field experiments were conducted during the 2021 and 2022 growing seasons at the Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt. Grain yield and nutrient concentration data were used to classify observations into high-yielding (≥ 8 t ha^{-1}) and low-yielding (< 8 t ha^{-1}) populations. Concentrations of N, P, K, Ca, Fe, Zn, Mn, and Cu were determined in grain samples and used to calculate nutrient ratios, variance parameters, and preliminary DRIS norms. Relationships between grain yield and major nutrient ratios were further evaluated using scatter plot analysis.

Results

The high-yielding population exhibited greater nutritional stability and lower variability in nutrient relationships than the low-yielding population. Several nutrient ratios, particularly N/P, N/K, N/Fe, K/Fe, and Zn/Mn, showed strong discriminatory capacity between yield groups and were selected as important components of the proposed **DRIS** norms. High grain yields were generally associated with narrower nutrient-ratio ranges, indicating that balanced nutrient interactions were more closely related to productivity than individual nutrient concentrations. Variations in N, K, Fe, Zn, and Mn were identified as major contributors to differences in crop performance.

Conclusions

The preliminary **DRIS** norms developed in this study provide a useful framework for nutritional diagnosis of rice under Egyptian production conditions. The results highlight the importance of nutrient balance in determining crop productivity and demonstrate the potential of **DRIS** as a decision-support tool for fertilizer management. Further validation across different cultivars, environments, and growing seasons is required before large-scale application.

Introduction

Rice (*Oryza sativa L*.) is one of the most important staple food crops worldwide and serves as a primary source of calories for billions of people. In Egypt, rice cultivation contributes substantially to food security, farm income, and rural livelihoods, particularly within the Nile Delta region where environmental conditions are favorable for its production. However, increasing pressure on agricultural resources, including limited freshwater availability, soil degradation, salinity development, and rising fertilizer costs, has intensified the need for more efficient nutrient management strategies capable of sustaining productivity while minimizing environmental impacts (**Abdelhameed *et al*. 2021; Elbasiouny *et al*. 2022; Seleiman *et al.* 2023; Zhu *et al*. 2024).** Plant nutrition remains one of the most influential factors governing crop growth and yield formation. The effectiveness of fertilizer programs depends not only on the supply of individual nutrients but also on the balance among nutrients within plant tissues. Nutrient imbalances may reduce nutrient uptake efficiency, restrict physiological processes, and ultimately limit crop productivity even when adequate quantities of fertilizers are applied. Consequently, reliable methods for evaluating plant nutritional status are essential for developing effective nutrient management recommendations (**Wang *et al*. 2022; Hu *et al.* 2024**). Conventional diagnostic approaches, including critical nutrient concentrations and sufficiency ranges, have been widely used to assess crop nutritional status. Although these methods provide useful information, they evaluate nutrients individually and often fail to account for the complex interactions that occur among essential elements within plants. Numerous studies have demonstrated that crop performance is frequently controlled by nutrient balance rather than the concentration of a single nutrient, highlighting the limitations of traditional diagnostic systems when applied to intensive agricultural production (**Urano *et al*. 2020; Silva *et al*. 2022**). To overcome these limitations, the Diagnosis and Recommendation Integrated System (DRIS) was developed as a nutritional diagnostic approach based on nutrient relationships rather than individual nutrient concentrations. The fundamental principle of DRIS is that nutrient ratios observed in high-performing crops can be used as reference standards for evaluating nutritional balance in other plant populations. By identifying nutrients that deviate from optimal relationships, DRIS facilitates the diagnosis of deficiencies, excesses, and nutrient imbalances while providing a more integrated assessment of plant nutritional status (**Walworth and Sumner 1987; Ramakrishna *et al*. 2009; Ndzié *et al*. 2021).** Recent advances in crop nutrition research have renewed interest in DRIS and related nutrient-balance approaches. Applications of DRIS have been reported in cereal, fruit, vegetable, and industrial crops, where the method has proven useful for identifying yield-limiting nutrients and improving fertilizer management decisions. Furthermore, recent reviews indicate that nutrient-balance diagnostics are becoming increasingly important within precision agriculture frameworks because they support site-specific nutrient management and more efficient use of agricultural inputs (**Kumar *et al*. 2024; Bueno *et al*. 2025).** Despite the economic importance of rice in Egypt, information concerning DRIS norms specifically developed under Egyptian production conditions remains limited. Most available nutrient standards were established using datasets obtained under different climatic conditions, soil characteristics, crop management practices, and genetic backgrounds. Such differences may influence nutrient dynamics and reduce the accuracy of imported diagnostic standards when applied to local production systems. Therefore, establishing region-specific DRIS norms is an important step toward improving nutrient diagnosis and optimizing fertilizer recommendations for Egyptian rice cultivation

(**Mahmoud *et al*. 2020; Elbasiouny *et al.* 2022**). The development of locally calibrated nutritional standards may contribute to improved nutrient-use efficiency, reduced fertilizer losses, enhanced crop productivity, and more sustainable rice production. Accordingly, the objectives of the present study were (i) to establish preliminary DRIS norms for rice grown under Egyptian conditions, (ii) to evaluate nutrient relationships associated with contrasting yield levels, and (iii) to identify nutrient expressions that may serve as useful indicators of nutritional balance and crop productivity.

Material and Methods

Experimental Site and Data Collection

The present study was based on field experiments conducted during two consecutive rice-growing Summer seasons (2021 and 2022) at the Rice Research and Training Center, Sakha, Kafr El-Sheikh Governorate, Egypt. The experiments were originally established to evaluate different nutrient management practices under irrigated rice production systems. Fourteen treatments representing combinations of mineral nitrogen, organic amendments, and biofertilizer applications were arranged in a randomized complete block design with three replications. Each experimental plot measured 12 m² (3 × 4 m). Rice cultivar Sakha 101 was used throughout the study. Seedlings were raised in nursery beds and transplanted 30 days after sowing at a spacing of 20 cm between hills. Standard agronomic practices recommended for rice cultivation in the Nile Delta were followed during both growing seasons. Prior to transplanting, composite soil samples were collected from the 0–30 cm soil layer and analyzed for selected physical and chemical properties according to standard procedures. Grain yield was determined at harvest and expressed on a hectare basis.

Plant Analysis

Representative grain samples were collected from each experimental unit at harvest. Samples were oven-dried at 65°C until constant weight, finely ground, and digested using the sulfuric acid–hydrogen peroxide method described by **Cottenie (1980).** Total nitrogen was determined using the micro-Kjeldahl procedure, phosphorus was measured colorimetrically using the molybdenum blue method, and potassium concentration was determined using flame photometry. Micronutrients including Fe, Zn, Mn, and Cu were quantified using atomic absorption spectrophotometry following the procedures described by **Chapman and Pratt (1961).**

Development of Preliminary DRIS Norms

A nutrient database was established using grain yield and nutrient concentration data obtained from all experimental observations. The database included concentrations of N, P, K, Ca, Fe, Zn, Mn, and Cu. To develop preliminary Diagnosis and Recommendation Integrated System (DRIS) norms, observations were classified into two productivity groups according to grain yield. Plots producing ≥ 8.0 t ha^{-1} were assigned to the high-yielding population, whereas plots producing < 8.0 t ha^{-1} were classified as the low-yielding population. The threshold value was selected to ensure adequate representation of highly productive plants while maintaining sufficient observations for statistical evaluation.All possible pairwise nutrient ratios were calculated from the measured nutrient concentrations. For each nutrient ratio, descriptive statistical parameters including mean, standard deviation, coefficient of variation (CV),

and variance were calculated separately for both yield populations. The nutrient-ratio approach was adopted because nutrient interactions often provide more reliable information about crop nutritional status than individual nutrient concentrations alone (**Walworth and Sumner 1987; Ndzié *et al*. 2021; Kumar *et al*. 2024**). The mean values of nutrient ratios obtained from the high-yielding population were considered preliminary DRIS norms because they represent nutrient relationships associated with superior crop performance. To evaluate the discriminatory capacity of each nutrient expression, variance ratios were calculated by dividing the variance of the low-yielding population by that of the high-yielding population (VL/VH). Ratios exhibiting larger variance ratios were considered more effective for distinguishing balanced from nutritionally imbalanced plants (**Walworth and Sumner 1987; Ramakrishna *et al*. 2009).**

Statistical Analysis

Descriptive statistical analyses were performed using Minitab Statistical Software (Version 22, Minitab LLC, State College, PA, USA). Mean values, standard deviations, coefficients of variation, and variance ratios were calculated for nutrient concentrations and nutrient-ratio expressions. Scatter plots were generated to investigate relationships between grain yield and major macronutrient ratios, including N/P, P/N, N/K, K/N, P/K, and K/P. These graphical analyses were used to evaluate nutrient balance patterns associated with variations in rice productivity and to support the interpretation of DRIS norms.

Table (1): Some Physical and chemical properties of studied soil.

Particle size distribution		**Chemical properties**	
Sand (%)	11.56	Soil pH (1:2.5 soil: water)	8.25
Silt (%)	33.42	Soil EC (1: 5) (dS m^{-1})	2.00
Clay (%)	54.22	Organic matter (%)	1.20
Textural class	Clayey		
Macronutrients		**Micronutrients** DTPA-extractable	
Available nitrogen (kg fed^{-1})	34.20	DTPA-extractable iron (ppm)	123.2
Available phosphorus (kg fed^{-1})	16.78	DTPA-extractable zinc (ppm)	31.32
Available Potassium (kg fed^{-1})	132. 1	DTPA-extractable manganese (ppm)	22.38
Available Calcium (kg fed^{-1})	21.16	DTPA-extractable copper (ppm)	11.07

Results and Discussion

Yield Stratification and Nutrient Characteristics of High- and Low-Yielding Rice Populations

The classification of the experimental observations into high-yielding (≥ 8.0 t ha^{-1}) and low-yielding (< 8.0 t ha^{-1}) populations provided the basis for developing preliminary DRIS norms for rice grown under Egyptian conditions (Table 2). The high-yielding population achieved an average grain yield of 9.14 t ha^{-1} compared with 6.98 t ha^{-1} for the low-yielding population, indicating substantial differences in crop performance that were associated with variations in plant nutritional status. The nutrient composition of grain samples revealed noticeable differences between the two yield groups. High-yielding plants

generally exhibited greater concentrations of most measured nutrients together with lower variability, suggesting a more stable nutritional environment during crop growth. In contrast, the low-yielding population showed larger fluctuations in nutrient concentrations, reflecting greater nutritional imbalance and less efficient nutrient utilization. Nitrogen concentration was markedly higher in the high-yielding population and was accompanied by a substantially lower coefficient of variation. Because nitrogen is directly involved in chlorophyll formation, photosynthetic activity, protein synthesis, and grain development, its adequate supply is strongly associated with increased rice productivity. Similar relationships between nitrogen availability, nitrogen use efficiency, and grain yield have been reported in modern rice production systems (**Wang *et al.* 2022; Hu *et al*. 2024; Farooq *et al*. 2024).** Potassium also showed a clear association with productivity. The relatively low variability observed in the high-yielding population suggests that balanced potassium nutrition contributed to maintaining physiological processes related to osmotic regulation, enzyme activation, assimilate translocation, and stress tolerance. Previous studies demonstrated that improving potassium management enhances nutrient use efficiency and promotes stable yield formation in rice (**Zörb *et al*. 2021; Chen *et al*. 2024**). Phosphorus concentrations were generally higher in productive plants, supporting the concept that adequate phosphorus availability is essential for energy metabolism, root activity, and reproductive development. The comparatively stable phosphorus status observed in the high-yielding population may have contributed to improved nutrient acquisition and more efficient grain filling. Similar findings have been reported by **Li *et al*. (2021**), who emphasized the critical role of phosphorus in rice yield formation and nutrient use efficiency. Among the secondary and micronutrients, calcium, iron, zinc, manganese, and copper also exhibited distinctive patterns between the two yield populations. High-yielding plants tended to maintain more consistent micronutrient concentrations, whereas greater fluctuations were observed in low-yielding plants. These results suggest that micronutrient balance contributes significantly to crop productivity through its effects on photosynthesis, enzymatic activity, oxidative stress regulation, and nutrient transport processes. Previous investigations have highlighted the importance of Fe, Zn, Mn, and Cu in sustaining physiological efficiency and maximizing grain production under intensive rice cultivation systems (**Bashir *et al*. 2021; Rehman *et al.* 2021; Alloway 2023; Zhang *et al*. 2024).** The lower coefficients of variation recorded for several nutrients within the high-yielding population indicate that superior crop performance was associated not only with nutrient abundance but also with greater nutritional stability. This observation supports the fundamental principle underlying the DRIS approach, which emphasizes nutrient balance and interactions rather than individual nutrient concentrations alone (**Walworth and Sumner 1987; Urano *et al*. 2020; Ndzié *et al.* 2021**). Consequently, the high-yielding population was considered the most appropriate reference group for establishing preliminary DRIS norms for rice under Egyptian agro ecological conditions.

Table (2). Mean, coefficient of variation (CV), variance and variance ratio between the low- and high yielding populations (S^2L/S^2H) of both yield and nutrient contents in rice grain at high- and low- yielding populations [1]

Variable	Population	Mean	CV(%)	Variance (S2)	S^2_L/S^2_H
Yield (ton ha^{-1})	High	9.144	6.62	0.365	0.512
	Low	6.984	6.19	0.187	
N (g kg^{-1})	High	17.408**	5.18	0.813	2.653
	Low	15.060**	9.75	2.157	
P (g kg^{-1})	High	3.003	33.33	1.003	0.236
	Low	1.760	27.67	0.237	
K (g kg^{-1})	High	7.240	3.91	0.080	9.239
	Low	6.410	13.42	0.739	
Ca (g kg^{-1})	High	0.694	7.63	0.003	3.667
	Low	0.582	18.05	0.011	
Fe (mg kg^{-1})	High	11.487	15.76	3.274	3.130
	Low	8.368	38.25	10.246	
Zn (mg kg^{-1})	High	6.379	24.16	2.374	0.155
	Low	3.876	15.66	0.368	
Mn (mg kg^{-1})	High	18.654**	28.38	28.023	0.408
	Low	11.012	30.72	11.442	
Cu (mg kg^{-1})	High	6.753	29.07	3.852	0.168
	Low	3.925	20.48	0.647	

(1) High- yield ≥ 8 ton ha^{-1}, low-yield < 8 ton ha^{-1}; mean yield and foliar nutrient contents of low- and high-yielding populations are significantly different at the 5% (**)

Development of Preliminary DRIS Norms and Nutrient Ratio Analysis

The nutrient-ratio approach revealed substantial differences in nutritional equilibrium between high- and low-yielding rice populations (Table 3). Unlike individual nutrient concentrations, nutrient ratios provide insight into the interactions among elements that collectively regulate plant growth and productivity. Consequently, DRIS norms derived from nutrient ratios are considered more effective for identifying nutritional constraints and prioritizing corrective management practices (**Walworth and Sumner 1987; Ndzié *et al*. 2021; Kumar *et al*. 2024)**. Several nutrient expressions exhibited considerable differences in variance between yield populations. Ratios such as N/P, N/K, N/Ca, N/Fe, K/Ca, K/Fe, Fe/Zn, Zn/Mn, and Mn/Zn showed relatively large variance ratios (S^2L/S^2H), indicating greater nutritional instability within

the low-yielding population. This pattern suggests that yield reduction was associated with disruption of nutrient balance rather than deficiency of a single element. Similar observations have been reported in DRIS-based evaluations of cereal and horticultural crops, where nutritionally balanced plants consistently exhibited lower variability in nutrient relationships and superior productivity (**Urano *et al*. 2020; Silva *et al*. 2022; Bueno *et al*. 2025**). Nitrogen-related nutrient ratios were particularly informative. The narrower distribution of N/P and N/K ratios in the high-yielding population indicates a more synchronized acquisition and utilization of these essential macronutrients. Nitrogen drives protein synthesis and canopy development, whereas phosphorus and potassium regulate energy transfer, assimilate transport, and grain filling processes. Any disruption in these interactions can limit nutrient use efficiency and reduce yield potential (**Zhang *et al*. 2020; Wang *et al*. 2022; Chen *et al*. 2024**). Calcium-associated nutrient ratios also contributed significantly to distinguishing productive from less productive plants. Calcium plays a fundamental role in membrane stability, intracellular signaling, root growth, and nutrient transport. The relatively stable Ca-related ratios observed in high-yielding rice suggest improved physiological coordination and enhanced nutrient movement within plant tissues. Similar relationships between calcium balance and crop performance have been reported by **White and Broadley (2022) and Raza *et al*. (2023).** Micronutrient interactions showed particularly strong diagnostic potential. Ratios involving Fe, Zn, and Mn displayed some of the largest variance ratios among all evaluated nutrient expressions. These micronutrients participate in chlorophyll biosynthesis, photosynthetic electron transport, enzymatic activation, antioxidant defense systems, and stress adaptation mechanisms. Consequently, disturbances in their balance may directly affect plant metabolism and grain production. Recent studies have highlighted the importance of maintaining adequate Fe, Zn, and Mn nutrition for sustaining rice productivity under intensive cultivation systems (**Bashir *et al*. 2021; Rehman *et al*. 2021; Alloway 2023; Zhang *et al*. 2024)**. The observed differences between yield populations support the fundamental DRIS concept that crop productivity is strongly associated with nutrient balance rather than absolute nutrient concentration. Therefore, the nutrient ratios derived from the high-yielding population represent valuable preliminary DRIS norms for diagnosing nutritional constraints in Egyptian rice production systems. These findings agree with recent DRIS applications in sugarcane, sesame, fruit crops, and cereal production systems, which demonstrated the effectiveness of nutrient-ratio diagnostics for identifying yield-limiting factors and improving fertilizer recommendations (**Rajammal *et al*. 2024; Kumar *et al*. 2024; Bueno *et al*. 2025; Mahmoud and Dizayee 2026).**

Table (3). Mean, coefficient of variation (CV %) and variance (S^2) of nutrient ratios of the low- and high-yielding populations, the variance ratio (S^2_L / S^2_H).

Nutrients ratios	High-yielding population			Low-yielding population			$S^2(L)/S^2(H)$
	Mean	C.V	Variance (S^2)	Mean	C.V	Variance (S^2)	
N/P	6.301	27.50	3.004	9.082	26.55	5.812	1.93
P/N	0.171	29.30	0.002	0.115	20.86	0.001	0.50
N/K	2.404	2.87	0.005	2.361	4.87	0.013	2.60
K/N	0.416	2.88	0.002	0.424	4.71	0.003	1.50
N/Ca	25.150	6.56	2.719	26.238	10.05	6.956	2.56
Ca/N	0.040	5.01	0.002	0.038	10.40	0.003	1.50
N/Fe	1.541	12.46	0.037	2.017	36.54	0.543	14.68
Fe/N	0.658	12.47	0.007	0.547	32.36	0.031	4.43
N/Zn	2.876	24.34	0.490	3.919	8.24	0.104	0.21
Zn/N	0.363	20.36	0.006	0.257	8.57	0.000	0.00
N/Mn	0.998	26.86	0.072	1.463	28.16	0.170	2.36
Mn/N	1.062	24.76	0.069	0.724	25.01	0.033	0.48
P/K	0.411	29.69	0.015	0.270	18.87	0.003	0.20
K/P	2.629	28.87	0.576	3.828	22.34	0.732	1.27
P/Ca	4.291	29.60	1.612	2.993	18.74	0.314	0.19
Ca/P	0.251	28.24	0.005	0.346	22.57	0.006	1.20
P/Fe	0.259	26.63	0.005	0.226	38.42	0.008	1.60
Fe/P	4.078	23.42	0.911	4.797	25.91	1.546	1.70
P/Zn	0.468	16.24	0.006	0.448	18.75	0.007	1.17
Zn/P	2.194	18.28	0.161	2.313	23.52	0.296	1.84
P/Mn	0.162	18.56	0.001	0.166	33.10	0.003	3.00
Mn/P	6.368	17.49	1.241	6.438	25.07	2.605	2.10
K/Ca	10.461	5.69	0.354	11.113	8.85	0.967	2.73
Ca/K	0.096	5.22	0.002	0.091	8.83	0.003	1.50
K/Fe	0.642	13.85	0.008	0.846	32.40	0.075	9.38
Fe/K	1.583	13.33	0.044	1.277	28.97	0.137	3.11
K/Zn	1.203	27.11	0.106	1.662	8.37	0.019	0.18

Zn/K	0.876	21.57	0.036	0.605	7.93	0.002	0.06
K/Mn	0.417	29.27	0.015	0.615	24.05	0.022	1.47
Mn/k	2.558	25.06	0.411	1.694	21.25	0.130	0.32
Ca/Fe	0.062	14.63	0.002	0.076	28.98	0.003	1.50
Fe/Ca	16.542	13.90	5.290	14.086	27.69	15.214	2.88
Ca/Zn	0.115	25.25	0.001	0.150	9.33	0.000	0.00
Zn/Ca	9.140	21.05	3.703	6.708	9.29	0.388	0.10
Ca/Mn	0.040	27.69	0.002	0.055	21.67	0.003	1.50
Mn/Ca	26.636	23.94	40.669	18.726	20.71	15.047	0.37
Fe/Zn	1.856	15.68	0.085	2.115	28.37	0.360	4.24
Zn/Fe	0.551	16.15	0.008	0.510	32.53	0.028	3.50
Fe/Mn	0.640	16.72	0.011	0.746	13.53	0.010	0.91
Mn/Fe	1.598	15.27	0.060	1.359	12.88	0.030	0.50
Zn/Mn	0.346	10.11	0.001	0.373	25.47	0.009	9.00
Mn/Zn	2.915	10.46	0.093	2.824	25.60	0.523	5.62

Yield–Nutrient Ratio Relationships

The relationships between grain yield and major macronutrient ratios are illustrated in (Fig1). The scatter distributions revealed that maximum grain yields were generally associated with relatively narrow nutrient-ratio intervals, whereas lower yields were distributed across a much wider range of nutrient relationships. This pattern indicates that achieving balanced nutrient interactions is more important for productivity than maintaining high concentrations of individual nutrients. The N/P and P/N relationships demonstrated that grain yield responded strongly to the balance between nitrogen and phosphorus. High-yielding observations were concentrated within relatively restricted ratio ranges, while greater dispersion was observed among low-yielding observations. Nitrogen and phosphorus function synergistically in photosynthesis, ATP production, assimilate partitioning, and reproductive development. Consequently, an imbalance between these nutrients may reduce nutrient use efficiency and limit yield formation (**Zhang *et al*. 2020; Wang *et al.* 2022; Rocha *et al*. 2024)**. A similar trend was observed for the N/K and K/N ratios. Grain yield tended to decline when nutrient ratios deviated substantially from the values observed in the high-yielding population. Potassium is involved in enzyme activation, stomatal regulation, carbohydrate transport, and tolerance to environmental stress, while nitrogen primarily controls vegetative growth and protein synthesis. Maintaining an appropriate balance between these nutrients is therefore essential for sustaining physiological efficiency and maximizing grain production (**Zörb *et al.* 2021; Chen *et al.* 2024; Liu *et al*. 2025**). The P/K and K/P relationships further demonstrated

the importance of nutrient equilibrium during grain development. High-yielding rice plants were concentrated within relatively stable ratio intervals, whereas lower-yielding plants exhibited greater variability. This observation suggests that coordinated phosphorus and potassium nutrition contributes to efficient assimilate transport and grain filling, ultimately enhancing yield performance (**Li *et al*. 2021; Chen *et al*. 2024**). The absence of a clear linear relationship between grain yield and individual nutrient ratios indicates that rice productivity is governed by complex nutrient interactions rather than isolated nutrient effects. These findings support the theoretical foundation of the DRIS methodology, which evaluates nutritional status through nutrient balance and interrelationships instead of independent nutrient concentrations. Similar distribution patterns have been reported in previous DRIS investigations involving cereal and horticultural crops (**Urano *et al*. 2020; Ndzié *et al*. 2021; Kumar *et al*. 2024)**. Overall, the clustering of high-yield observations within specific nutrient-ratio ranges provides strong evidence that balanced nutrition is a key determinant of rice productivity and confirms the suitability of the proposed nutrient ratios for developing preliminary DRIS standards under Egyptian growing conditions

Study Limitations

Although the present investigation successfully established preliminary DRIS norms for rice cultivated under Egyptian conditions, several limitations should be acknowledged. First, the dataset was generated from a single experimental location within the Nile Delta region and may not fully represent the diversity of soil types, climatic conditions, irrigation practices, and management systems encountered across all rice-growing areas of Egypt. Second, the proposed norms were developed using data obtained from one rice cultivar under specific agronomic treatments. Nutrient requirements and nutrient interactions may vary among cultivars due to differences in genetic background, nutrient uptake efficiency, and yield potential. Third, the database used for DRIS norm development was derived from a limited number of growing seasons. Seasonal variation in temperature, water availability, and soil nutrient dynamics can influence plant nutritional status and may affect the stability of nutrient-ratio standards.

Therefore, the proposed norms should be considered preliminary and require validation using larger datasets encompassing multiple locations, years, cultivars, and management conditions. Future studies should also compare DRIS with other modern diagnostic approaches, including compositional nutrient diagnosis (CND) and machine-learning-based nutrient assessment models, to improve the accuracy and practical applicability of nutrient recommendations for sustainable rice production.

Conclusion

The present study established the first preliminary DRIS norms for rice grown under Egyptian production conditions using nutrient concentration and nutrient-ratio data derived from contrasting yield populations. The results demonstrated that highly productive rice plants were characterized by greater nutritional stability and more balanced nutrient interactions than low-yielding plants. Nutrient-ratio analysis showed that interactions among N, P, K, Ca, Fe, Zn, and Mn provided stronger discrimination

between productive and less productive plants than individual nutrient concentrations alone. Several nutrient expressions exhibited substantial differences in variability between yield groups, highlighting their potential value for nutritional diagnosis and fertilizer management. The observed clustering of high yields within specific nutrient-ratio ranges further emphasized the importance of nutrient equilibrium in achieving optimum rice productivity. These findings support the use of DRIS as a practical diagnostic framework for identifying nutritional constraints and improving nutrient-use efficiency in rice production systems. Although additional validation is required across different agro ecological regions and rice cultivars, the proposed norms provide an important foundation for future nutrient management programs and may contribute to the development of more precise, economically efficient, and environmentally sustainable fertilizer recommendations for Egyptian rice cultivation.

Abbreviations

CV
Coefficient of Variation
S
Variance
H
High yield
L
Low yield
NPK
Micronutrient(Nitrogen, phosphorus, potassium)
Ca,Fe,Zn,Mn
Macronutrient
B G A
Blue green Algaa
DRIS
Diagnosis and Recommendation Integrated System

Declarations

Data availability

All data generated or analyzed during this study are included in this published article.

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E.A.B designed and performed the experiment, responsible of physiological analysis of the manuscript and also wrote and reviewed the manuscript.

S.E. designed and performed the experiment and also wrote and reviewed the manuscript**.**

H.H. deigned and performed the experiment, all authors have read and agreed to the published version of the manuscript.

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Author details

1-Plant Nutrition Department, National Research Centre, 33 El-Behouth St, 12622, Dokki, Cairo, Egypt

2-Field crops Department, National Research Centre, 33 El-Behouth St, 12622, Dokki, Cairo, Egypt

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Figures

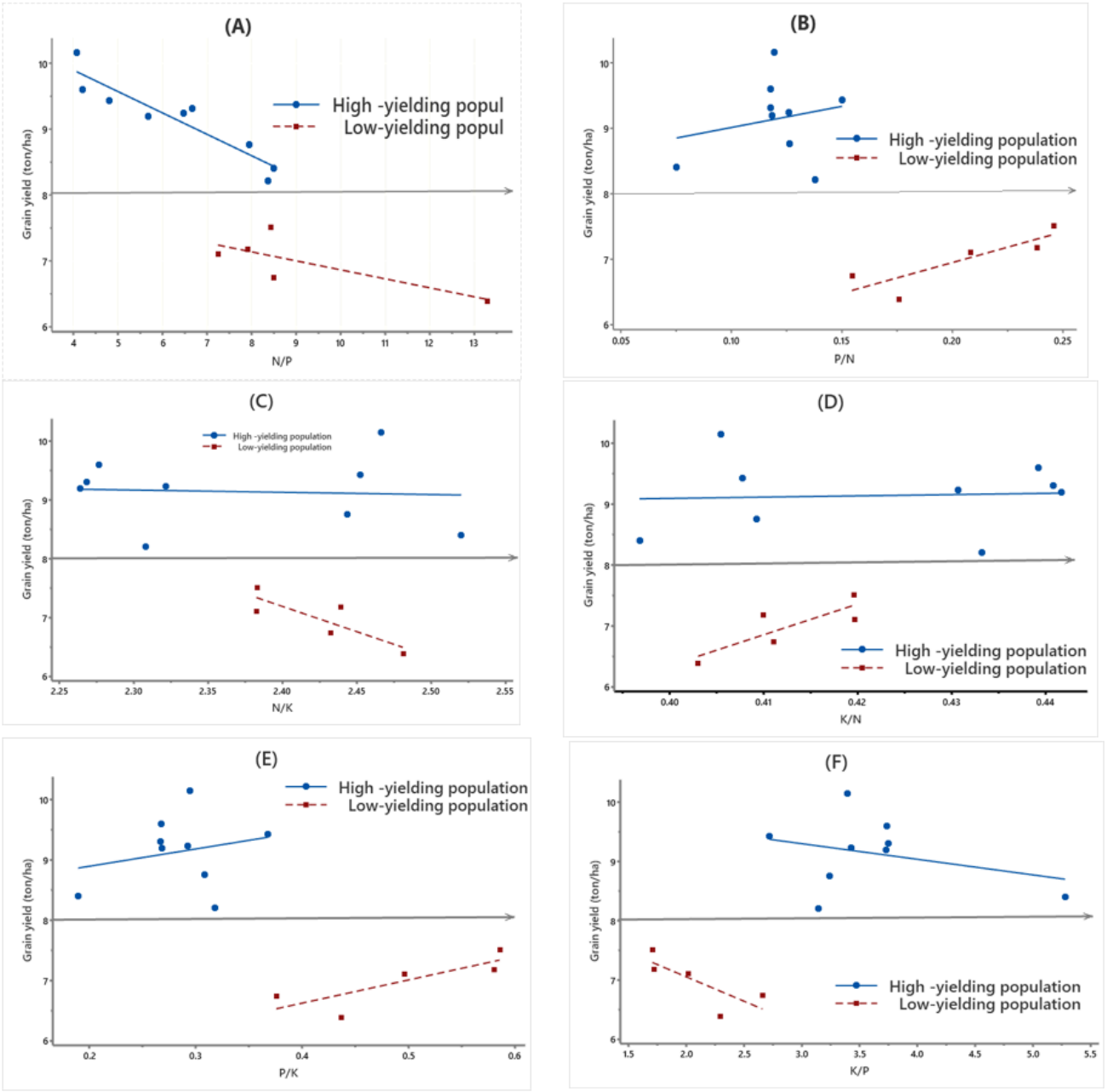


Figure 1

Scatter diagram showing a non –Gaussian distribution of yield versus the N/P ratio (A), Versus P/N (B), Versus P/N (B), Versus N/K (C), Versus K/N (D), Versus P/K (E), Versus K/P (F) in Rice grain.