

The status of microelements in the selected ERPP irrigation schemes in Unguja and Pemba Islands, Zanzibar

ABSTRACT

Aims: updating u the status of microelements in the selected expanding rice production project irrigation schemes in Unguja and Pemba Islands, Zanzibar

Study design: Standard grid soil survey

Place and Duration of Study: Unguja and Pemba Isles Zanzibar during October and December, 2017.

Methodology: Detailed soil survey was conducted using pedogeomorphic approach and composite soil samples were collected at a depth of 0 – 30 cm for microelements investigation from each of the delineated mapping units.

Results: Results showed that the status of micronutrients (Fe, Zn and Mn) in the selected irrigation

schemes varied ($P \leq 0.05$) with schemes and their respective mapping units, although in some cases, variations were not ($P \leq 0.05$) significant. In Unguja and Pemba irrigation schemes, there were generally moderate or optimum DTPA - extractable Fe, low DTPA - extractable Zn and high DTPA - extractable Mn levels. The data suggests that except for DTPA - extractable Zn which was low in all irrigation schemes, Fe and Mn were not limiting to crop growth and development. However, in Kwalempona (KWA-MP1: Hi1) and Machigini (MA-MP1: Hi1) irrigation schemes, Fe levels were rated as low or below critical limits. Additionally, the overall soil reaction in these irrigation schemes ranged from neutral (N) to very strongly acid (VSA).

Conclusion: In all, these results suggest that in order to improve crop production in the selected irrigation schemes, low Zn availability should be addressed by including it into fertilizer programs as well as proper soil pH management by reducing acidity through liming in the higher elevations and addition of organic matter (OM) in the plain or valley mapping units. Application of OM in the plain or valley mapping units may ensure slow release of the micronutrients at levels which are sufficient to support plant growth during and or after the implementation of the Expanding Rice Production Project (ERPP) irrigation development.

Keywords: [ERPP, pH, cation exchange capacity, rice, soil microelements, management practices, soil organic matter, survey]

Abstract must according to the format of the journal

1. INTRODUCTION

define and describe briefly ERPP irrigation schemes

Soil fertility which is determined by the presence and availability of. macro

and micronutrients.. Micronutrients in soils,

also referred to as trace elements (TEs), microelements or heavy metals are mineral elements (give ref)

required by plants in small quantities to orchestrate a range of physiological functions [1; 2; 3; 4]. In soils, these micronutrients occur in soils at concentrations $< 100 \text{ mg kg}^{-1}$ with density $> 5 \text{ mg m}^{-3}$ [5; 6]

and to large extent belong to the group of "transition elements" of the periodic table. Although

microelements such as Iron (Fe), Zinc (Zn) and Manganese (Mn) are required in minute quantities by

plants for growth and development [7], their availability varies [8] and their uptake in excess to the plant requirements results in toxic effects [9; 10]. In global terms, Sillanpää [11] estimated that the area of micronutrient - deficient in agricultural soils is 49 % in Zn, 10 % in Mn and 3 % in Fe. As a result, more than half the human population is deficient in Fe and at least half is deficient in Zn [12].

25

26 Iron (Fe) is an essential micronutrient for almost all living organisms because it plays critical role in
27 metabolic processes such as DNA synthesis, respiration, and photosynthesis. Iron is the fourth most
28 abundant element in the earth's crust but it is the third-most limiting nutrient for plant growth
primarily
29 due to its low solubility in aerobic environments [13; 14]. In fact, over one third of the world's soils
are

30 considered Fe deficient. Iron is essential for chlorophyll development and function, energy
transfer
31 within the plant, a constituent of many enzymes and proteins, functions in plant respiration,
plant
32 metabolism and N₂-fixation. Without sufficient Fe, carbon (C) cannot be extracted from CO₂ and O₂
33 cannot be properly used in the plant. The yellow and red colors of most soils are caused
by Fe
34 compounds, and so, most soils possess enough Fe for plant needs. Fe gives the soil its
characteristic
35 color as a result of leaching of other soluble elements leaving Fe behind. Although abundant in most
36 well-aerated soils, the biological activity of Fe is low because it primarily forms highly insoluble ferric
37 compounds at neutral pH levels. Occasionally, rice grown in a low Fe paddy soil can become
deficient
38 in Fe due to precipitation of FeS. Iron deficiency is therefore a yield-limiting factor with
major
39 implications for field crop production in many agricultural regions of the world [15]. This can be
easily
40 corrected by addition of old nails or other iron source to the soil.

41

42 Zinc (Zn) is a metal of over 300 enzymes [16; 17] and is considered to be the most
critical
43 micronutrient [18; 19] as it affects the synthesis of protein, structure and functions of membrane [20],
44 expression of genes and oxidative stress tolerance in plants [17; 21]. Zinc is required to maintain the
45 integrity of ribosome and takes part in plant development due to its catalytic action in metabolism for
46 all crops [22; 23]. Several enzymes such as carbonic anhydrase, alcohol dehydrogenase,
superoxide
47 dismutase and RNA polymerase contain Zn. Similarly, Zn takes part in the formation of
carbohydrates
48 and catalyzes the oxidation processes in plants, provides a structural role in many
transcription
49 factors and is a cofactor of RNA polymerase. Therefore, Zn deficiency reduces plant growth
and
50 inhibits photosynthesis in many plants [24], fiber crops [25], rice [26], and spinach [27]; retards the
51 activity of carbon metabolism enzymes such as carbonic anhydrase [25; 28], ribulose
1,5-
52 bisphosphate carboxylase/oxygenase and fructose-1,6-bisphosphate [18].

53

54 Zinc deficiency not only retards growth and yield of plants, but it also has effects on human beings.
55 More than 3 billion people worldwide are suffering from Fe and Zn deficiencies, and this condition is
56 particularly widespread in areas where population is heavily dependent on an unvaried diet of cereal
57 based foods, in which Fe and Zn are stored almost exclusively in the husk, and are therefore lost
58 during milling and polishing [29; 30]. More than 30 % world's population suffers from Zn deficiency
59 [31]. Zinc plays a part in the basic roles of cellular functions in all living organisms and is also
involved

60 in improving the human immune system. The optimum dietary intake for human adults is 15 mg Zn
61 per day. Zinc acts as a catalytic or structural component in various body enzymes.

Unsatisfactory

62 intake and improper absorption of Zn in the body may cause deficiency of Zn. Due to Zn deficiency;
63 the human body will suffer from hair and memory loss, skin problems and weakness in body
muscles.

64 Further insufficient intake of Zn during pregnancy also causes stunted brain development of the
fetus.

65 Infertility has also been observed in Zn deficient men. Zinc deficiency may cause congenital
diseases

66 like *Acrodermatitis enteropathica* [32; 33; 34].

67

68 Manganese (Mn) plays an important role in reactions of enzymes like mallic dehydrogenase
 69 and oxalosuccinic decarboxylase. It is also needed for water splitting at photosystem II and for
 70 superoxide dismutase. In plants, Co complex is found in the form of vitamin B12. The cation Mn^{2+} is known to
 71 substitute Fe^{2+} and Mg^{2+} in silicates and oxides. Manganese is essential to organisms,
 including
 72 microorganisms, plants, animals, and human beings. It is involved in many physiological and
 73 biochemical processes in plants as a cofactor of enzymes or as a catalyst and is thus a required
 trace
 74 mineral for all known living organisms. Little information is available on Fe, Zn and Mn
 status in
 75 Unguja and Pemba Islands. Understanding the status of these micronutrients will provide
 valuable
 76 information leading to improvements in micro-fertilizer management practices in the selected
 irrigation
 77 schemes

The title of the manuscript demands for comparison of various irrigation systems in the area with respect
 to their impact on soil texture, plant growth and nutrient availability and then role of micronutrients

78

79 2. MATERIAL AND METHODS

80

81 2.1 Study area

Describe mentioned areas with reference to their geographical position and also draw a map respective
 province or zone by highlighting locations

82

83 The study areas include four (4) irrigation schemes in Pemba and five (5) irrigation
 schemes in

84 Unguja Islands. The four irrigation schemes in Pemba include Machigini, Dobi, Ole and
 Kwalempona.

85 Machigini is located in Mkoani; Dobi and Ole are located in Chakechake (Pemba South)
 and

86 Kwalempona in Wete (Pemba North). The five irrigation schemes in Unguja include
 Bandamaji in

87 Kaskazin A (Kaskazin); Koani and Mchangani in Central district (Unguja South); Mtwango
 and

88 Kibonde Mzungu in Magharib B (Unguja West). The project areas receive seasonal rainfall ranging
 89 from 1,553 mm in Pemba Airport to 1,926 mm annum⁻¹ in Wete, Pemba. Average yearly
 rainfall

amounts to about 1,769 mm as compared with 1,449 mm annual evapotranspiration. The rainfall pattern is characteristically bi-modal with two rain seasons separated by dry season. Short rains (Vuli) begin October and end in December while long rains (Masika) usually start in March and ends in May. In Pemba survey areas, Masika rains comprise of an average of 57 % of the total rains compared with Vuli which comprise of 22 % of the total rains. Similarly, Masika rains in Unguja surveyed areas comprise of an average of 50 % compared with Vuli which comprise of 29 % of the total rains. Some of the study areas experiences seasonal flooding on the most of the valleys in some years (met reference).

The climate variables representative of the study areas in Pemba and Unguja are presented in Table

4. In Pemba, the mean temperature varies from 26.6°C in July/August to 29.6°C in February. The monthly average relative humidity (RH) varies from 75 % (i.e. July/August) to 83.0 % (i.e. April and November). The potential evaporation is about 1,449 mm per annum and varies widely throughout the year from 97 to 145 mm per month in July and January respectively. In Unguja, the mean temperature varies from 24.9°C in September to 28.4°C in February. The monthly average relative humidity (RH) varies from 78 % in August to 86 % in April. The potential evaporation is about 2,386 mm per annum and varies widely throughout the year from 177.9 to 225.5 mm per month in May and January respectively.

2.2 Soil samples collection and preparation

Base maps were prepared following pedogeomorphic approach indicating mapping units representing landforms. Conventional soil mapping techniques were used to collect soil sample from natural pedogenic horizons. Eighteen (18) topsoil samples (i.e. composite samples) were collected from different mapping unit at each representative profile or minipit at a depth of 0 – 30 cm of the selected irrigation schemes in Pemba and Unguja Islands. The depth (cm) of natural horizons, colours and soil structure were determined using FAO Guidelines for Soil Description [35]. The soil samples were air- dried for 10 consecutive days in the soil chemistry laboratory of the National Soil Service Mlingano, Tanga, Tanzania (NSS) and later sieved to pass through a 2 mm sieve to remove debris. Part of the air-dried soil samples were oven dried to a constant mass at a temperature of 105°C for 24 hours. These were used for all the chemical and physical analysis.

Type of soil sampler used

How many samples were drawn from a sample unit area

Weather it was random or selective sampling scheme

2.3 Determination of Plant-available Minerals in Soils

The trace elements Fe, Zn and Mn were extracted from soil using di-ammonium ethylenediaminetetraacetic (EDTA) acid solution [36] modified by Beyers and Coetzer [37]. The extractants were analysed for Fe, Zn and Mn using ICP-MS spectrometry (IRIS/AP HR DUO Thermo Electron Corporation, Franklin, Massachusetts, USA).

2.4 Statistical Analysis

The statistical analysis was performed using the 2-way analysis of variance (ANOVA) in factorial arrangement, with the computations being performed with the software program STATISTICA. The fisher's least significance difference (L.S.D.) was used to compare treatment means at $P \leq .05$ level of significance [38].

3. RESULTS AND DISCUSSION

3.1 Unguja

3.1.1 Dobi Irrigation Scheme

Results of the status of microelements in the selected irrigation schemes in Unguja are presented in **Tables 2-1, 2-2, 2-3 and 2-4**. The data showed that Fe, Zn and Mn were different ($P \leq .05$) within the mapping units but not pH. In Dobi Irrigation scheme, Mn ranged from 4.7 to 6.3 mg kg⁻¹, and was greater ($P \leq .05$) in DB - Hi1 compared with the other mapping units. The proposed deficiency levels for Mn (DTPA) in the soil are 1.0 - 5.0 mg·kg⁻¹ and the values greater than 140 - 200 mg·kg⁻¹ were regarded as

excess [11;39; 40]. The observed levels of DTPA extractable Mn in this study were therefore considered as normal or sufficient for plant growth and development [40].

er, Fe and Zn were comparatively greater ($P \leq .05$) in DB - Va11 and DB - Va12 compared with DB - Hi1 mapping unit. Likewise, the data showed that Zn ranged from 0.5 – 0.7 mg kg⁻¹ and Fe from

26.1 - 32.9 mg kg⁻¹. These were rated as low and very high for DTPA extractable Zn and Fe respectively [41]. The proposed critical levels for DTPA extractable Fe in the soil for instance, ranged

from 0.3 – 10 mg·kg⁻¹ [11; 40; 42; 43]. Nevertheless, Fe toxicity or deficiency could occur at low and high pH, respectively. From this study the level of DTPA extractable Fe was 32.9 mg·kg⁻¹ which was rated as above the critical levels. Higher levels of DTPA extractable Fe may pose soil fertility problems such as P - fixation, B deficiency, Fe and Mn toxicity [44; 45; 46]. The critical values of Zn were 2.0 - 5.0 mg·kg⁻¹ and the values greater than 10 - 20 mg·kg⁻¹ were regarded as excess [11]. In

this study, DTPA extractable Zn showed to be below the critical levels which may affect crop production. The low level of DTPA extractable Zn in DB irrigation scheme was probably attributed to pH whereby Zn showed to decrease as pH increased just as previously reported by Kiekens [47]. Low Zn in the study area could also be due to seasonally flooded soil conditions [48] as a result of Zn reaction with free sulphide [49]. Under the submerged conditions of rice cultivation for example, Zn is changed into amorphous sesquioxide precipitates or franklinite; ZnFe₂O₄ [50].

Table 2-1: The status of some microelements in Dobi Irrigation Scheme in Unguja Island

	pH		Mn	Zn	Fe
	(H ₂ O)	(KCl)			
DB-Va11	5.73a	4.52a		4.68c	0.73a
32.90a DB-Va12	5.43a	5.33a		5.59b	0.54a
29.98a DB-Hi1	6.33a	4.43a		6.30a	0.50b
26.12b One - Way ANOVA (<i>F</i>-Statistic)					
MU	1.8ns	3.2ns		25.5**	49.8***
15.6**					
CV (%)	10.0	10.0		5.0	5.1
5.0					

Values followed by dissimilar letters in the same column are significant at $P \leq .05$; CV = Coefficient of variation; KCl = Potassium Chloride; H₂O = Water; Mn = Manganese; Zn = Zinc; Fe = Iron

for crop growth. Whereas Mn was greater ($P \leq .05$) in KWA – Hi1 compared with the other mapping units, Zn was lowest ($P \leq .05$) in KWA – Hi1 compared with KWA - Va11 and KWA - Va12 mapping units located in the valley landscape. These values ranged from 4.8 mg kg⁻¹ in KWA - Va11 to 19.9 mg kg⁻¹ in KWA – Hi1 and 0.2 mg kg⁻¹ in KWA – Hi1 to 0.4 in KWA –

Va11 for Mn and Zn respectively. The proposed deficiency level for DTPA extractable Mn in the soil varied from 2.0 - 5.0 mg kg⁻¹ with values > 140 - 200 mg kg⁻¹ regarded as excess [11]. These values are rated as within or above the critical limits but not excess for crop growth. The proposed deficiency

level for Zn (DTPA) in the soil was 0.4 - 0.6 mg kg⁻¹ and values greater than 10 - 20 mg kg⁻¹ were regarded as excess [11]. Based on this rating, all mapping units in Kwalempona irrigation scheme had adequate Zn levels in the soil for crop growth and development.

Table 2-2: The status of some microelements in Kwalempona Irrigation Scheme in Unguja

	Island pH (H ₂ O)	pH (KCl)	Mn	Zn mg.kg ⁻¹	Fe
KWA-Va11	5.9a	5.2a		4.8b	0.4a
36.3a KWA-Va12	6.0a	5.3a		5.7b	0.4a
31.8b KWA-Hi1	6.9a	6.2a		19.9a	0.2b
23.5c					

In Kwalempona
Irrigation
Scheme, DTPA
- extractable Fe
ranged from
23.5 mg kg⁻¹ in
KWA – Hi1 to
36.3 mg kg⁻¹ in
KWA - Va11
(Table 2-2).
Results show
that DTPA -
extractable Fe
was greater (P
 $\leq$
.05) in KWA –
Va11
compared with
the rest of the
mapping units.
The proposed
critical level for
various crops
varied from 0.3
to 10 mg kg⁻¹
[42] suggesting
that Fe in the
study area was
above the
critical limits,
thus, sufficient

Table

2 3 3 I h e s t a t u s o f s o m e m i c r o e l e m e n t s i n M a c h i g i n i l r i g a t i o	n Scheme in Unguja Island pH pH Mn				
	Zn	Fe			
	(H ₂ O)	(KCl)		mg.kg ⁻¹	
	MA-Va1	5.10a	4.40a	9.58c	0.65a
	27.92b MA-Va2	5.10a	4.38a	16.80a	0.48b
	30.31a MA-Hi1	5.73a	5.03a	14.50b	0.50b
	21.96a One - Way ANOVA (<i>F-Statistic</i>)				
	MU	1.5ns	1.9ns	83.8***	36.0***
			30.6***		

CV (%) 9.7 10.0 5.1 5.1 5.0

Values followed by dissimilar letters in the same column are significant at $P \leq .05$; CV = Coefficient of variation; KCl = Potassium Chloride; H₂O = Water; Mn = Manganese; Zn = Zinc; Fe = Iron

3.1.4 Ole Irrigation Scheme

In Ole irrigation scheme, there was significant ($P \leq .05$) difference between the mapping units in the Fe, Zn and Mn contents (Table 2-4). Results showed that DTPA – extractable Fe ranged from 43.7 to 52.9 mg kg⁻¹ and was rated as high [41]. The critical DTPA – extractable Fe content beyond which crop growth is impaired is 4.5 mg kg⁻¹ [52]. The EDTA - extractable Fe was lowest ($P \leq .05$) in OLE - Pa1 located on the Plain landscape compared with other mapping units. These results suggest that DTPA – extractable Fe is not a constraint in crop growth and production in all the mapping units in Ole irrigation scheme.

The data showed that the status of DTPA – extractable Zn ranged from 0.6 to 0.8 mg kg⁻¹ and was rated as low [41; 56]. Similar to Fe, the EDTA - extractable Zn was lowest ($P \leq .05$) in OLE - Pa1 located on the Plain landscape compared with other mapping units. The critical Zn content beyond which crop growth is impaired is 1 mg kg⁻¹ [65]. The low Zn contents in the surveyed mapping units in Ole irrigation scheme probably is due to high content of free Fe, Al and Mn ions which caused adsorption of Zn to non - exchangeable form on their hydrated oxides surface [60]. MacBride [61] observed that the presence of other divalent cations such as Ca²⁺ greatly reduces the efficiency of heavy metals adsorption by permanent charge soil colloids.

Results also showed that DTPA – extractable Mn in the surveyed mapping units in Ole irrigation scheme ranged from 7.7 to 14.9 mg kg⁻¹ and was rated as high [62]. The DTPA - extractable Mn was lowest in OLE – Pa2 compared with other Mapping units. The critical DTPA - extractable Mn level beyond which crop growth is affected is 1 mg kg⁻¹ [62]. The proposed deficiency level for Mn (DTPA) in the soil varied from 2.0 - 5.0 mg kg⁻¹ with values > 140 - 200 mg kg⁻¹ regarded as excess [11]. These results suggest that Mn is not a limiting factor for crop production in the study area.

Table 2-4: The status of some microelements in Ole Irrigation Scheme in Unguja Island

	pH		Mn	Zn	Fe
	(H ₂ O)	(KCl)		mg.kg ⁻¹	
OLE-Pa1	5.87a		5.16a	14.87a	0.59c
43.07c OLE-Pa2	5.37a		4.67a	7.66c	0.82a
52.89a OLE-Pa3	5.63a		4.92a	11.26b	0.71b
47.98b One- Way ANOVA (<i>F-Statistic</i>)					
MU	0.6ns		0.7ns	114.9***	31.1***
12.5**					
CV (%)	9.8		17.5	5.2	5.0
5.0					