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RESEARCH ARTICLE

WATER SAVING INNOVATION IN URBAN LANDSCAPING AND IRRIGATED AGRICULTURE BY USING AUSTRABLEND®MULTI MINERAL ROOT ZONE CONDITIONER

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ABSTRACT

Water scarcity is a major issue in the hot climate countries including the GCC region where total evapotranspiration is less than the total precipitation. These countries rely on non-conventional water resources such as costly desalinated water, saline ground water and treated sewage effluent to meet their requirements for agriculture and urban landscapes. To be sustainable for agriculture production for food security it is essential to be self-sufficient within national boundaries, which is not the case with water scarce countries, where the food deficit is met through import and heavy investments. Increasing local food production within national boundaries should be considered a top priority for two reasons, to save financial resources and to have locally available food with quality control. Expansion of agriculture in these countries is not a viable option due to degradation of land resources and water scarcity. Any method which intensifies agriculture and saves water should be taken as a priority. This is possible through adopting water saving technologies and improving soil health to increase nutrient and moisture holding capacities, such as, but not necessarily limited to the use of organic and inorganic soil amendments. Considering these deficiencies in agriculture production and urban landscape management, two trials were initiated, 1) forage intensification and 2) urban landscape management by using soil amendments such AustraBlend®Multi Mineral Root Zone Conditioner (ABMMRZC) alone and in combinations with green compost and biochar using deficit irrigation. ABMMRZC is mined from Australia, it is original and rich in nontronite clay minerals having the high cation-exchange-capacity to attract nutrients and moisture. Greenhouse pot trials revealed that ABMMRZC has the potential to intensify fresh barley biomass production at deficit irrigation (50% ETc). Notably, the fresh biomass with ABMMRZC application at 50% ETc is 39% greater than the control or higher than fresh biomass obtained at 100% ETc without ABMMRZC application. Similarly a trial on grassy landscape (*Paspalum vaginatum*) has confirmed over three times fresh biomass production with the application of 10 tons ABMMRZC per hectare and thus guaranteeing 50% water saving. The efficiency of ABMMRZC was further confirmed through structure development in grass root zone resulting in reduced bulk density from 1.56 g/cm^3 (native sandy soil) to 1.25 g/cm^3 with ABBMMRZC application. The results support ABMMRZC as an added value in agricultural intensification and sustainable management of urban landscapes in water scarce countries. It is a water saving material as well as containing macro (NPK) and micronutrient (Fe, Cu, Mn, Zn).

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INTRODUCTION

Water scarcity is commonly observed in many countries especially those located in the dry lands where climate is hot and rainfall is insufficient to meet the demand of agriculture and urban landscapes. This necessitates the use of either groundwater which is usually saline and limits the choice for crop selection or using costly desalinated water and treated sewage effluent (TSE). The use of TSE, many times questioned due to its source, especially for the root crops which have direct contact with the TSE and may cause diseases. On the other hand the misuse of saline water has caused abandonment of many agricultural farms due to low productivity. The United Nations University-Institute for Water, Environment and Health (UNU-INWEH) stated that globally, irrigated lands cover some 310 million hectares, an estimated 20 percent of it salt-affected (62 million hectares). The inflation-adjusted cost of salt-induced land degradation in 2013 was estimated at US$441 per hectare, yielding an estimate of global economic losses at US$27.3 billion per year. Every day for more than 20 years, an average of 2,000 hectares of irrigated land in arid and semi-arid areas across

75 countries have been degraded by salt (UNU-INWEH). It is assumed that current extent of degradation could be higher, and should be considered a serious and major concern, considering population is likely to rise to over 9.0 billion by 2050. To avoid food shortage and to meet the increased demand for healthier and nutritious food of the current and growing population, agricultural production must increase 60% globally and 100% in developing countries. The UNU-INWEH notes that the UN-FAO projects to produce 70 percent more food by 2050, including a 50 percent rise in annual cereal production to about 3 billion tons. Considering the UAE, its renewable water resources are limited as rainfall is less than 100 mm per year and lack of freshwater resources is a serious constraint to agricultural development in the UAE. Agriculture already accounts for >80% of the water withdrawals in the region and increasing competition for good-quality water among different water- use sectors is expected to limit severely the availability of freshwater for irrigation. Globally water use has been growing at more than twice the rate of population increase in the last century and there will be significant increase in water withdrawals by 2025, i.e., 50% more in developing countries and 18% more in developed countries. In the context of the Middle East and North Africa (MENA) region, water scarcity is one of the most important food-security issues, with fresh water availability in the region expected to drop 50% by 2050 (World Bank, 2007). By 2025, 1800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. Therefore water security is important for long term use of water resources. *Water security* is the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks. Climate change, droughts, and higher frequency and intensity of extreme weather events has led to increased water scarcity which has threatened food security and nutrition in dry lands. To address these issues the policies, technologies, and institutions for sustainable intensification will be critical for building resilience in dry lands, in terms of enhanced agricultural production on a sustainable basis.

In the past many years urbanization has increased to an unprecedented level which has raised concerns about the sustainability of cities. Sustainability seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future (United Nations World Commission on Environment and Development, 1987). In this regards Andersson (2006) has presented urban landscapes in the context of sustainable cities linking between biodiversity and ecosystem function, the role of humans in ecosystems, landscape connectivity, and resilience. Urbanization results in an environment that is compositionally more heterogeneous, geometrically more complex, and ecologically more fragmented (Zhang *et al.,* 2004), and may represent the most complex mosaic of vegetative land cover and multiple land uses of any landscape (Foresman *et al.,* 1997). Regardless of any type, land cover is used to present aesthetically attractive landscapes, these landscapes can only be successful through costly maintenance, most important of which is the irrigation management under harsh climatic condition, in addition to timely pruning and nutrient replenishment to offset nutrient requirement of plants. The water management becomes more important in regions where water scarcity is the main issue and irrigation is met through costly desalinated water or TSE which has concerns over its safe use without causing human health issues. Considering these significant issues in urban landscapes and agricultural production, it is essential to find innovative ways to reduce irrigation water quantity without compromising the landscapes quality, groundwater contamination and enhancing agricultural production when sandy soil is used to establish parks, football pitches and urban landscapes and agricultural farms. There are many organic (compost, biochar, biofertilizer, manures) and inorganic amendments in the market which has been tested to improve soil health and intensify agriculture production with the objective of water saving (Al-shankiti *et al.,* 2015; Shahid *et al.,* 2016). A number of amendments have been used eg bentonite (IWMI, 2010), sodium lignosulfonate products (Raffaeli, 2009) to improve soil health to boost crop production. The use of Bentonite (smectite family of clay) in Thailand at the rate of 1.25 tons per ha resulted in an average rice yield increase of 73% (IWMI, 2010). Soils that contain high levels of particular clays like smectites, are often very fertile (IWMI, 2010). It attracts positively charged cations like NH_4^+ and K^+ which are then released when demanded by plants. Taking the results of several such field trials of forage sorghum, scientists recorded a sixfold increase in biomass production after applying bentonite and mixing it with the soil using a rotavator or disc plough. The increase in soil quality by a single application of clay persisted for at least 3 years. Through multiple testing in the UAE, the AustraBlend®Multi Mineral Root Zone Conditioner (ABMMRZC) has shown great promise in 50% water saving in grassy landscape (Gill, 2018) and increasing crop productivity with guaranteed significant water saving (Shahid *et al.,* 2016; Gill *et al.,* 2016, 2018).

In the UAE (EAD, 2009; EAD-MoEW, 2012; Shahid *et al.,* 2013, 2014), Kingdom of Saudi Arabia (MAW, 1985), Oman (MAF 1990), Kuwait (KISR, 1999) and Qatar (Schiebert *et al.,* 2005) the soils are dominantly sandy (Entisols) and present low cation-exchange-capacity (CEC) and hence are infertile and require frequent irrigations and nutrients application for crop production and maintenance of urban landscapes. Water saving requires improving the water use efficiency through innovative ways such as climate smart technologies. In this regard, a number of organic and inorganic amendments have been used by various researchers to improve water and nutrient use efficiencies. However, little has been done in this respect on UAE soils, and hence this subject has formed the focus of this study, involving ABMMRZC, green waste compost and biochar alone and in different combination tested in the laboratory, the green house and extensively under field conditions. In this paper results from a greenhouse trial producing barley forage through significant water saving and grassy landscape maintenance has been presented and discussed.

MATERIALS AND METHODS

What is AustraBlend®Multi Mineral Root Zone Conditioner?

AustraBlend (ABMMRZC) is olive gray on Munsell soil color chart (Plate 1), mined from Australia and is rich in nontronite clay mineral. Nontronite is Fe rich member of smectites-triphormic phyllosilicate clay minerals group. It consists of two silica tetrahedron sheets and sandwiched alumina octahedron sheet termed as 2:1 type of clay minerals.

Plate 1. Olive gray AustraBlend®MMRZC mined from Australia

The ABMMRZC is acquired from Australia and is a product of AustraBlend Pty Ltd Queensland. Its mineralogical analysis was completed at QUT Central Analytical Research Facility-Institute for Future Environments Australia and the routine analyses was performed at the Environmental Analytical Laboratory of Southern Cross University Australia. The analysis of the sandy soil (soil texture, ECe, pHs, ESP, $CaCO_3$ eq) and water (EC, Sodium Adsorption Ratio-SAR, Residual Sodium Carbonates-RSC) used in both the trials was completed in the Central Analytical Laboratory (CAL) of the International Center for Biosaline Agriculture Dubai, UAE. The CAL uses the procedures described by Soil Survey Staff (2014a). ABMMRZC consists of macronutrients (Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) as well as micronutrients (Iron (Fe), Copper (Cu), Manganese (Mn), Zinc (Zn), Nickle (Ni), Cobalt (Co) and Vanadium (V) (Table 1). This shows that it is not only water saving but also improves soil fertility with less dependence on fertilizers. It has neutral pH, and no salinity and sodicity problems. The soil texture is sandy loam (Soil Science Division Staff, 2017) and 21% field capacity (4 time higher than sandy soil).

Table 1. Routine ABMMRZC analysis report

Parameter (unit)	Value
EC (1:5) dS/m	0.037
pH (1:5)	7.52
ESP	1.4
CEC (cmol+/kg)	26.0
$CaCO_3$ (%)	1.5
Gravel (2mm) %	12.6
Sand (%)	63.0
Silt (%)	32.7
Clay (%)	4.3
Texture (USDA)	Sandy loam
Bulk density (g/cm^3)	1.40
Organic matter (%)	0.9
Phosphorus (Bray 2) mg/kg	112
NO_3-N (mg/kg)	5.6
NH_4-N (mg/kg)	1.1
Available K (mg/kg)	49
DTPA extractable↓	
Fe (mg/kg)	20.0
Cu (mg/kg)	0.7
Mn (mg/kg)	7.6
Zn (mg/kg)	0.6
C/N	23.9
Volumetric moisture ($cm^{3/cm3}$) %	43.0
Water content (10 bars) %	25.0
Water content (33 bars) %	21.0
Water content (15 bars) %	12.0
Water content air-dried (40ºC)	5.0

Characterization of green compost and biochar

Table 2 presents selected characteristics of green compost (GC) and biochar. To be consistent the EC and pH has been determined on a 1:10 soil: water (w/v) basis. The GC and biochar present higher salinity levels. The pH is also variable, highest being in GC (pH 7.82-moderately alkaline). The GC is nutritious relative to biochar. Biochar was produced through pyrolysis process using date palm feedstock. The native sandy soil used in the trials is non-saline and non sodic, strongly calcareous and fine sand soil texture (Table 3).

Table 2. Routine analysis report of green compost and biochar

Characteristics	Green compost	Biochar
Munsell color (dry)	Very dark grey (5YR 3/1)	Black
Munsell color (moist)	Dark reddish brown (5YR 3/2)	Black
EC (1:10) dS/m	8.95	13.72
pH (1:10)	7.82	7.45
Organic matter (%)	30.0	74.82
Nitrogen	1.2%	70 mg/kg
Phosphorous	0.40%	15.8 mg/kg
Potassium	2.25%	7.96 mg/kg

Table 3. Routine soil analysis report

Characteristics	Soil
ECe (dS/m) (EC of soil saturation extract)	0.885
pHs (pH of saturated soil paste)	7.11
Exchangeable Sodium Percentage (ESP)	6.0
CaCO3	38.0
Sand (%)	99.0
Silt (%)	0.5
Clay (%)	0.5
Texture (Soil Science Division Staff 2017)	Fine sand
Field capacity (%)	5.5

Taxonomic class of sandy soil used in trials

The sandy soil used in both trials is classified as Mixed, Hyperthermic Typic Torripsamments. Where ***Mixed*** is the mineralogy class, ***Hyperthermic*** is soil temperature regime (the mean annual soil temperature is 22ºC or higher, and the difference between mean summer and mean winter soil temperature is more than 6ºC at a depth of 50 cm from the soil surface) and ***Typic torripsamment*** indicates typical desert sandy soil at soil subgroup level of USDA Soil Taxonomy (Soil Survey Staff, 2014b; Shahid *et al.,* 2014).

X ray diffraction analysis (XRDA) of ABMMRZC

Sample preparation

The sample was dried in an oven at 40 °C overnight. The dried sample was then crushed in a stainless steel swing mill in repeated short bursts until it passed a 300 µm sieve. A sub-sample (2.7 g) was accurately weighed and a specimen prepared for X-ray diffraction analysis (XRDA) by the addition of a corundum (0.3 g, Al_2O_3) internal standard at 10% by weight. The specimen was micronised in a McCrone mill using zirconia beads and ethanol, then dried in an oven overnight at 40 °C. The resultant homogenous powder was back-pressed into a sample holder. A step scanned XRD pattern was collected for half an hour using a PANalytical X'Pert Pro powder diffractometer and cobalt Kα radiation operating in Bragg-Brentano geometry. The collected data was analyzed using JADE (V2010, Materials Data Inc.) and X'Pert Highscore Plus (V4, PANalytical) with various reference databases (PDF4+, AMCSD, COD) for phase identification.

Rietveld refinement was performed using TOPAS (V5, Bruker) for quantitative phase analysis. The known concentration of added corundum facilitates reporting of absolute phase concentrations for the modelled phases. The sum of the absolute concentrations is subtracted from 100 % weight to obtain a residual (called non- diffracting/ unidentified, also known as "amorphous"). The residual represents the unexplained portion of the pattern: it may be non-diffracting content but will also contain unidentified phases or poorly modelled phases. It is not an accurate measure as its error is the sum of the errors of the modelled phases. An absorption contrast correction (Brindley) was made on the basis that the average size of the particles in the specimens is approximately 5 µm. Please note powder XRD is bulk phase analysis, it is not chemical analysis. Phase concentrations may be mis-estimated if an incorrect chemical formula is assigned to a phase. Therefore, the closest matches in the reference phase identification databases were used in the Rietveld refinement model, but other members of the identified mineral groups may be present.

Clay fraction isolated from ABMMRZC

A small portion of the crushed sample was dispersed in water. After sonication (5 min) and settling for 5 min, the fine fraction (nominally < 5 µm in suspension) was transferred via pipette to a low background plate and allowed to settle and dry. This preparation is used to concentrate the fine (clay dominant) fraction and aids identification of the clays present. The air dried slide was further treated in an ethylene glycol atmosphere (60 °C) for several hours, then immediately re-examined.

Characterization of AustraBlend MMRZC using X-Ray Fluorescence Spectroscopy

The ABMMRZC was characterized at Dubai Central Laboratory (Dubai Municipality) for elemental oxides composition (Table 4) using XRF equipment. The chemical composition revealed higher contents of silica dioxide relative to other elements, reflecting dominance of silicate and alumino-silicate minerals such as Nontronite and feldspar. The presence of Fe_2O_3 shows the probability Fe minerals (hematite, ilmenite), and Ti (rutile, brookite) and other minerals.

Water saving and forage intensification trial

In a greenhouse trial Barley (*Hordeum vulgare*) was grown in native sandy soil during December 2015-March 2016. Different rates of ABMMRZC, GC and biochar used including a control without any amendment. Fresh water (EC 0.43 dS/m) was used to offset water requirements (100% ETc, 75% ETc & 50% ETc). The standard rates of NPK for barley crop were used by using urea, triple super phosphate (TSP) and sulfate of potash (SOP) fertilizers. To test the performance of ABMMRZC fresh biomass was recorded. The quantities of the soil amendments were determined based on the surface area of the pot (0.0638 m^2) filled with 20 kg soil and correlated on per hectare basis (1 ha = 10,000 m^2). The soil and amendments based on the treatments were mixed using mechanical mixer (Plate 2). The treatments mixtures were mixed with upper half of the soil in the pot (10 kg) to simulate field conditions. In the bottom of the pot 10 kg soil (without amendment) was added prior to the addition of amendment-soil mixtures. The pots were arranged in three groups based on the irrigation water rates (50% ETc, 75% ETc & 100% ETc. Following treatments were used.

Treatment 0 = Control
T1 = ABMMRZC 30 tons/ha
T2 = ABMMRZC 30 tons/ha + 15 tons/ha G compost
T3 = ABMMRZC 30 tons/ha + G compost 15 tons/ha +
Biochar 15 tons/ha T4 = ABMMRZC 50 tons/ha

Seeding barley crop

Ten seeds were sown in each pot (2 in each hole) on 20 December 2015, once germinated the plants were thinned to

Table 4. Elemental oxides composition of AustraBlend® MMRZC

→Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	MnO_2	Na_2O	K_2O	LOI
……..………………………………………..……Average content %...											
AustraBlend MMRZC	46.22	14.18	15.19	6.81	4.08	0.01	2.54	0.25	1.69	0.91	4.68

LOI= Loss on ignition

Filling the pot with soil and amendment **Mixing soil-amendment in mechanical mixer**

Plate 2. Preparation of soil pots for green house experiment

five per pot on 4 January 2016. Seeds were placed about 1 cm deep in the soil and in equal distance and all seeds were geminated. From the date of sowing until 12 January 2016 all pots were irrigated at field capacity for seedling establishments. From 13 January irrigation was given based on the 50%, 75% and 100% ETc. The ETc was calculated based on the evaporation in the green house and crop coefficient (barley crop) at different growth stages using standard calculation procedures.

Evaluation for biomass production

The trial was harvested on 12 March 2016, immediately after harvesting weighing was done on-site to avoid losing moisture content. The fresh biomass from three replications of each treatment pots (0.191 m^2) was recorded and average per pot made for reporting. For better understanding of the effects of deficit irrigation and the use of amendments the results are presented separately as bar diagram for 50% ETc, 75% ETc and 100% ETc.

Urban Landscape Trial

A trial was conducted in a newly established grassy landscape in Sharjah, UAE. A plot of 13x37 meters (481 m^2) was selected where ABMMRZC was applied and a sprayer irrigation system was installed. A separate plot was selected as control (without ABMMRZC). Agriculture grade sandy soil was used to develop the rootzone layer with a mixture of animal manure to improve soil fertility and structure development. The plot was divided into 1x1 meter grids where ABMMRZC at the rate of 1 kg/m^2 was added (10 tons/ha) manually (Plate 3) and mixed mechanically in the upper 10 cm depth. The Paspalum vaginatum grass was planted in the entire plot using the stolons on 7 November 2017. The plot was irrigated with water of pH 7.58; EC = 4.97 dS/m; Sodium Adsorption Ratio-SAR = 15.1 (mmoles/L) $^{0.5}$ and no Residual Sodium Carbonates-RSC. Both plots (control and with ABMMRZC) were irrigated with normal irrigation rate (100% ETc) until 21 Feb. 2018 to sure that grass is fully established). After initial full irrigation, irrigation was reduced to 75% where ABMMRZC was applied (21 Feb. 2018 to 2 May 2018). The irrigation was further reduced to 60% on 2 May 2018, and to 50 % on 29 September 2018 and continued thereafter.

RESULTS AND DISCUSSION

Phase Identification and Quantification

The powder XRD pattern shows the presence of crystalline phases. A graphic of the collected diffraction pattern along with the phase concentration estimates identified is shown in figure 1 and table 5 respectively. The estimated normalised concentration of the corundum internal standard in the sample is higher than 10 % by weight. This means there is an unaccounted for component in the sample (i.e., the sample contains non-diffracting/unidentified material). The major crystalline phases identified and modelled are smectite (modelled as nontronite), calcium (between 0.5 – 0.65) substituted plagioclase, clinopyroxene (modelled as augite) and anorthoclase (Figure 1, Table 5). The presence of nontronite-smectites was further confirmed by ethylene glycolation of the clay sample (Figure 2). Due to crystal imperfections and isomorphous substitution nontronite presents high negative charges which attract positively charged nutrients (NH^{4+}, K^+, Mg^{2+}, Fe^{2+}, Cu^{2+}, Mn^{2+}, Zn^{2+}, Zn^{2+}) on their negatively charged surface (Plate 4) which are released to plants on demand. High negative charges are a source of cation-exchange-capacity (CEC) which determines soil fertility status of soil.

Table 5. Minerals phase concentration estimates in ABMMRZC

Mineral phase	Normal weight %, absolute
Quartz	0.3
Anatase	0.9
Ilmenite	2.8
Hematite	0.2
Siderite	0.6
Clinopyroxene (augite)	11.5
Anorthoclase	13.4
Plagioclase	27.9
Smectite (nontronite)	23.1
Non-diffracting (unidentified)	19.4

Effect of irrigation regimes on barley biomass production under control conditions – without amendment

The comparison of fresh biomass obtained from different irrigation rates (50% ETc, 75% ETC and 00% ETc) without soil amendments (T0) clearly shows that increasing trend of irrigation rate (figure 3) has increased the fresh biomass of barley. The increase being 25.1% and 42.3% at ETc 75% and ETc 100% respectively over fresh biomass obtained at 50% ETc. This is conventional practice whereby farmer is using standard fertilizer (NPK) practice without the addition of any amendment. This clearly confirms that increasing water rates under harsh climatic and desert conditions has a pivotal role in obtaining higher forage yields. Such conventional practices questions the long term availability of water for agriculture especially in water scarce region such the GCC countries. Therefore, we attempted to produce forage under deficit irrigation using ABMMRZC alone (T 1 and T4) and in various combination with green compost (T 2 and T3) and green compost and biochar (T3).

Fresh biomass production using AustraBlend®MMSC in different combinations

The comparison of fresh biomass obtained from different treatments (T1-T4) with control (T0) treatment (without any amendment) and irrigation regimes is presented in figure 3. The results clearly show that a reverse trend (as opposed to conventional practice-without amendments) of fresh biomass production has been recorded when amendments were used. In general, at deficit irrigation (50% ETc) higher fresh biomass was recorded relative to 75% ETc and 100% ETc. The results have revealed that ABMMRZC has the potential to intensify fresh biomass production at deficit irrigation, where 50% water may be saved (figure 4).

Notably, the fresh biomass at 50% ETc is either at par (T1) or higher (T2) than fresh biomass obtained at 100% ETc (without any amendment), suggesting 50% guaranteed water saving with amendments. Other treatments T3 and T4 have shown 1.7 and 5% decrease respectively compared with 100% ETc (without amendments). These are preliminary results under controlled conditions that has given us hope to test further under field conditions. We are hopeful that further field testing will pave the way further for upscaling ABMMRZC at larger scales.

Urban landscape trial

- ABMMRZC broadcasted on 1m^2 grid basis
- ABBMMRZC mixed with soil and leveled of

- Lush green dense grassy plot with ABMMRZC and 50% water saving (50% ETc)
- Pale yellow N-deficient grass less dense without ABMMRZC and 100% ETc

- Thick root system with ABMMRZC and 50% ETc
- Thin root system without ABMMRZC and 100% ETc

- Moist soil with ABMMRZC application (50% ETc), and coring for bulk-density measurement
- Dry soil without ABMMRZC application (100% ETc) and coring for bulk-density measurement

Plate 3. Progress of urban landscape trial with deficit irrigation (50% ETc) and full irrigation (100% ETc)

A 73% rice yield increases has been reported by IWMI (2010) in a trial in Thailand using bentonite clay.

Comparison of fresh biomass (grasses) with deficit irrigation in urban landscape

To assess the fresh biomass of grassy plots with ABMMRZC (deficit irrigation) and control plot (No ABMMRZC with 100% ETc irrigation) the grass was harvested at three times (2 August 2018; 22 September and 10 October 2018) during trial period. At this stage the plots were fully established with full irrigation (100% ETc) and final deficit irrigation (50% ETc). The harvested grass was weighed on-site to avoid losing moisture content.

The results show significantly higher fresh biomass with ABMMRZC application and deficit irrigation (figures 5,6,7). At three times fresh biomass was 1.8, 3.32 and 2.75 times higher in plot with ABMMRZC (with deficit irrigation-50% ETc) compared with the plot without ABMMRZC application but with 100% ETc irrigation level. The relative difference in higher biomass production with ABMMRZC is due to number of days grass was grown after harvesting dates. Visual difference of grass quantity (weight) and health (greenness) is shown in Plate 5.

Evaluation of structure development in grassy plots

The soil structure development was evaluated by taking undisturbed cores from the grass root zone to measure bulk

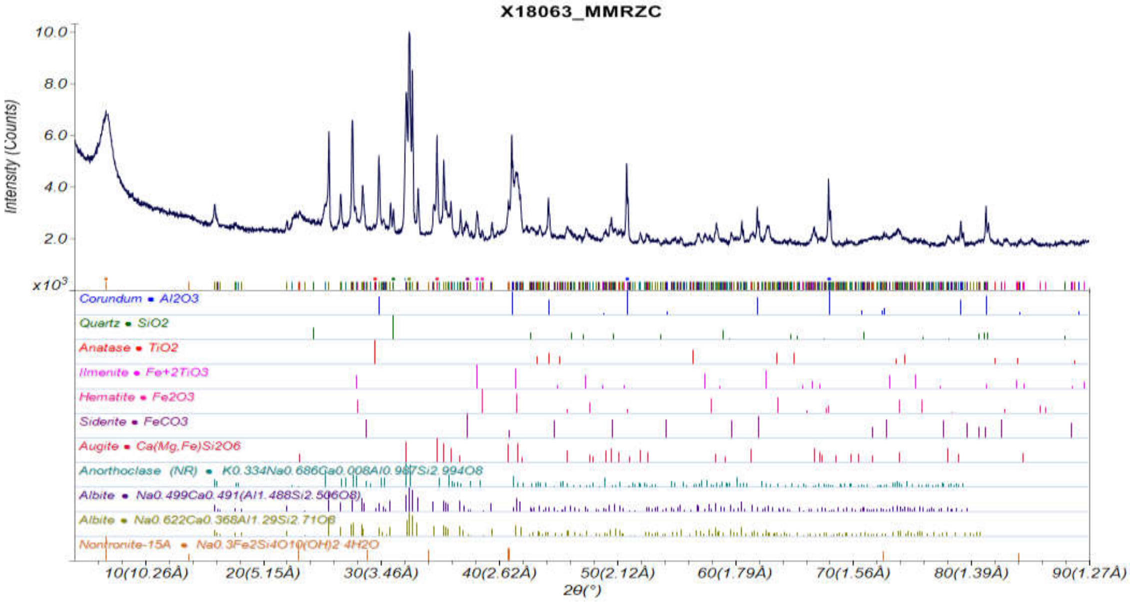


Figure 1. Powder x-ray diffraction pattern of ABMMRZC

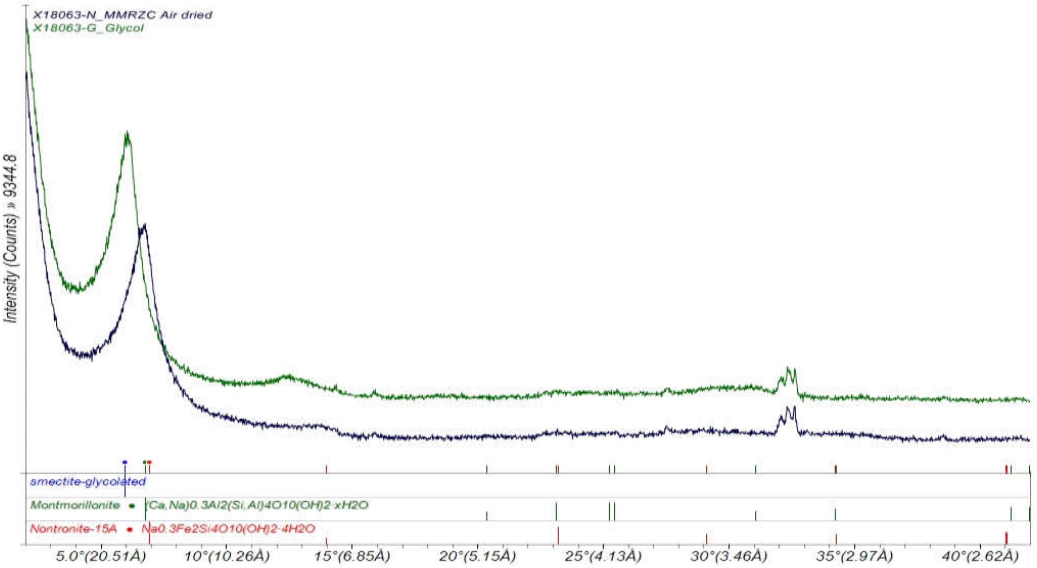
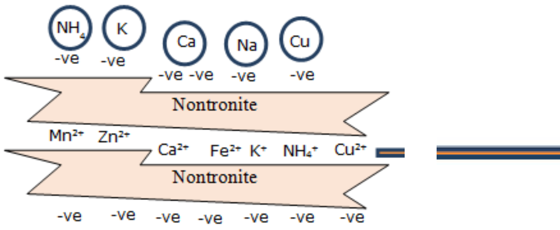
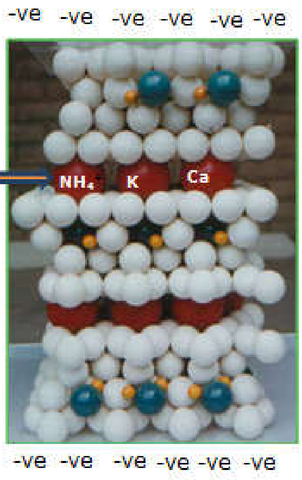


Figure 2. Fine fraction (clay) x-ray diffraction pattern



Nontronite clay lattice – Geometrical configuration of nontronite showing negative (-ve) charges at crystal edges and nutrient (positively charged) adsorption at negatively charged exchange sites.



Nontronite clay lattice – red balls are retained nutrients (NH_4, K, Fe, Cu, Mn, Zn etc); (white – oxygen (O); black embedded in tetrahedron (Si); yellow – aluminium (Al); green – Hydroxyls (OH).

Plate 4. Nontronite is negatively charged and retains nutrients and releases when needed by plant

density (Bd), a measure of oven dried mass of soil divided by bulk volume (including soil and volume occupied by roots and air space). The reduction in Bd value is considered as improvements in soil structure which ultimately improves nutrient and moisture holding capacities leading to higher plants biomass. In the present study the addition of ABMMRZC has reduced the Bd from 1.56 g/cm^3 (native sandy soil) to 1.4 g/cm^3 (control plot) and 1.25 g/cm^3 with the application of ABMMRZC and deficit irrigation.

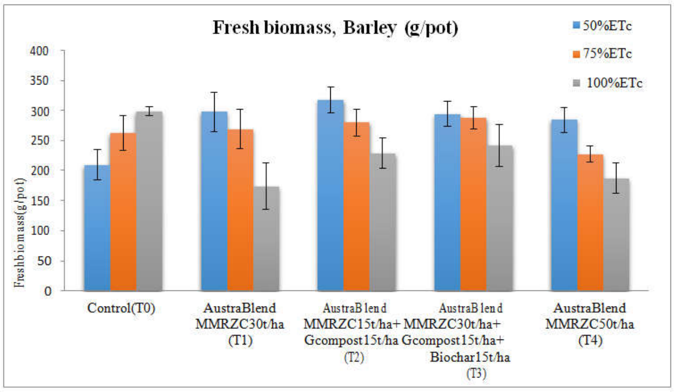


Figure 3. Comparison of fresh biomass production with various treatments

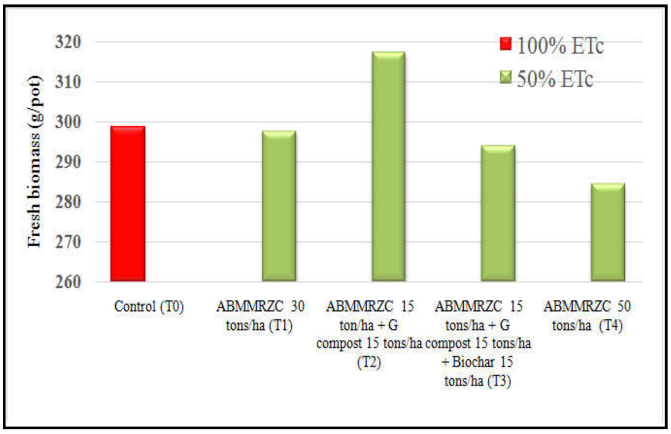


Figure 4. Fresh biomass at deficit irrigation with different amendment treatments

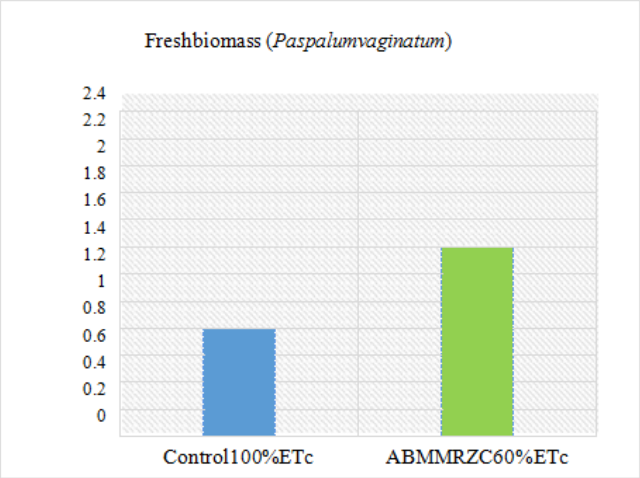


Figure 5. Relative fresh biomass of grass (4 m^2) from control plot (100% ETc no application of ABMMRZC) and 60% ETc application with ABMMRZC applied plot (2 August 2018) – 1.8 times biomass with ABMMRZC application

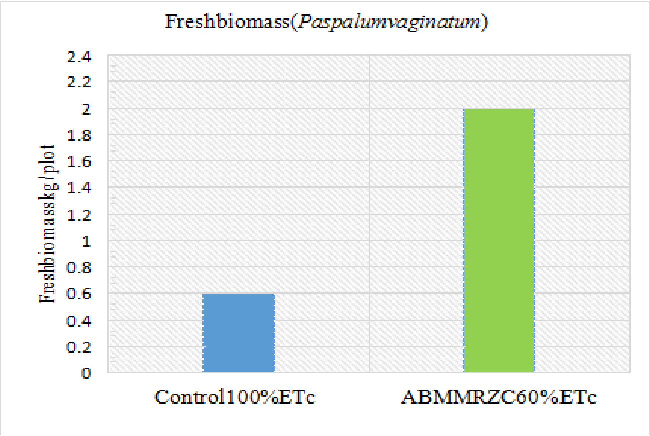


Figure 6. Relative fresh biomass from control and ABMMRZC applied grassy plot (4 m^2) (22 September 2018) – 3.32 times higher biomass with ABMMRZC application

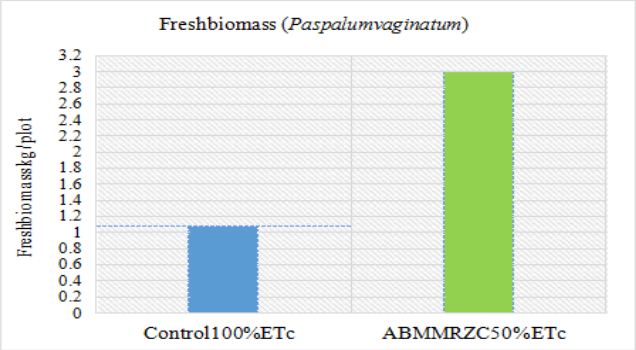


Figure 7. Relative fresh biomass from control and ABMMRZC applied grassy plot (4 m^2) (10 October 2018) – 2.75 times higher biomass with ABMMRZC application

Plate 5. Visual observation of biomass quantity and greenish appearance (harvested on 22 September) – Left (control plot 100% ETc), right (ABMMRZC with deficit irrigation 60% ETc)

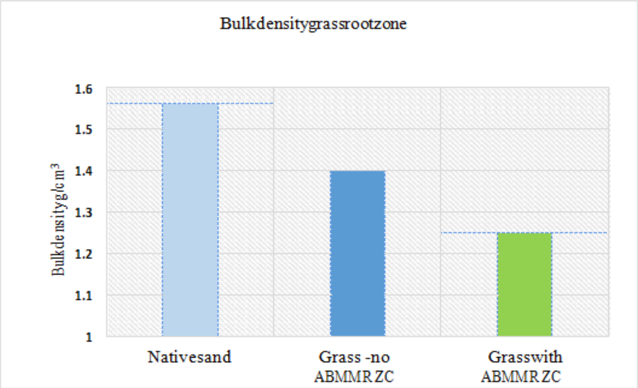


Figure 8. Relative bulk density of native sandy soil, grass field without ABMMRZC and with ABMMRZC

Justified reasons of using AustraBlend® in Agriculture farms and Urban landscapes (Polyclean 2018)

- It is natural, mined from Australia with no added chemicals (organic)
- It is non-saline, EC (1:5) is less than 0.04 deci Siemens per meter (dS/m).
- Over five times field capacity (fc 25 percent) relative to sandy soils of GCC countries
- Volumetric water content (0.01 bars) is 42 percent
- The Cation Exchange Capacity is 260 milli equivalents per kg
- pH (1:5) is optimum (7.52) for nutrients availability, as well as $CaCO_3$ is 1.6% and hence no phosphorous fixation.
- The silt plus clay is 37% which meets good quality soil texture (sandy loam) for agriculture farms and urban landscapes (turf grass).
- Guaranteed 50% water saving through improved sandy soil structure development
- Cost-effective maintenance of forages, turf grass and landscapes
- Increased crop per meter square with less irrigation (climate resilient).
- Reduced fertilizer application (low cost nutrient management).
- Controlled leaching and environmental protection.

Conclusions and recommendations

From the present study it is concluded that the health of infertile sandy soil can be significantly enhanced through using AustraBlend®Multi Mineral Root Zone Conditioner (ABMMRZC) to intensify forage production and cost-effective management of urban landscapes with guaranteed 50% water saving. ABMMRZC has shown great promise under UAE conditions and it is recommended for other countries where similar environmental and soil conditions may be existing such as GCC countries. In these countries pilot scale trials both on irrigated agriculture and urban landscapes are recommended prior to up-scaling to large scale utilisation.

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