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RESEARCH ARTICLE

ALFALFA *(MEDICAGO SATIVA)* AS FORAGE CROP AND ADOPTION OF BEST MANAGEMENT PRACTICES IN THE DESERT ENVIRONMENT OF UNITED ARAB EMIRATES

***Khalil Ur Rahman, Mohammed Khalifa Bin Thaleth and Khalfan Al Suwaidi**

Al Nakhli Management Office Dubai United Arab Emirates

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ABSTRACT

Forages are the backbone of livestock industry in any country and so is the case of United Arab Emirates where in addition to significant forage import local forage production is also gaining significant importance to control forage quality through organic farming. The soils of the UAE are dominantly sandy and infertile and hence show poor physical, chemical and fertility properties, suggesting frequent irrigation and replenishment of nutrients based on crop requirement. Among other forages alfalfa is grown in many farms. Alfalfa is salt sensitive crop (threshold salinity-ECe 2 dS/m) and could not tolerate high water salinity levels which is the general case of most of the agricultural farms in the UAE. Considering the salt-sensitive nature of alfalfa it is imperative to grow alfalfa in areas where there is sufficient recharge of the aquifer and water salinity is acceptable level. In other case local alfalfa can be grown with desalinated water if the purpose is to control the forage quality and direct feeding of fresh forage to camels and horses and through adopting organic farming technology. It is to be noted that a comparison between crop yield from organic and conventional farming cannot be compared, due to the use of heavy chemicals and fertilizers in the latter case. However, there are various options if properly adopted the health of sandy soils can be improved through enhancing soil quality using natural soil amendments like AustraBlend Multi Mineral Root Zone Conditioner (ABMMRZC) mined from Australia and adopting 4R nutrient stewardship as well as seed inoculation with rhizobium and mycorrhizae application. In this papers all possible options to increase alfalfa production including seed inoculation, mycorrhizae application, eradication of weeds, proper soil preparation, irrigation and nutrient management, remediation of autotoxication, growing high yield varieties, harvesting method have been briefed to enhance alfalfa in existing farms and to introduce in new farms with clear objective. Growing alfalfa locally have two very clear benefits compared to imported ones, that is, control on the quality of alfalfa forage and saving of financial resources with less import and ready availability of fresh fodder without hay making.

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INTRODUCTION

Despite the success of the green revolution, poverty and hunger remained major challenges in many parts of the world, particularly in developing countries located in the drylands with unprecedented population rise. Global population which was 0.6 billion in 1700 has increased to 7.2 billion in 2015 and 10.9 billion is projected by 2100. This shows that with population growth the global demand for food, forage and fuel will increase leading to overexploitation of land and water resources to gain more benefits and this will accelerate land degradation and destruction of the environment (Egamberdieva *et al.,* 2008). The very first status of the world's soil resource report has already alarmed that "*the majority of the world's soil resources are in only fair, poor or very poor conditionsand that conditions are getting worse in far more cases than they are improving* (FAO-ITPS, 2015).

Corresponding author: **Khalil Ur Rahman,**
Al-Nakhli Management Office Dubai United Arab Emirates

Despite the land resources are at high threats of degradation and considering the population growth it has been projected that b*y 2050*, agricultural production must increase by *60 % globally – and by almost 100 % in developing countries* – to meet food demand alone.Owing to the dryland conditions and geographic location the UAE receives scanty rainfall insufficient to recharge the aquifer, so there is imbalance between water abstraction and recharge resulting into fast depletion of water resources and increase of water salinity. The high salinity reduces the choices for crop selection, therefore, growing cereals (wheat, rice) in the open field is not viable option. However, under such conditions forages (sorghum, pearl millet, barley) can be grown by irrigation with saline water based on the salinity tolerance (threshold) level and following leaching requirement concept. Alfalfa *(Medicago sativa)* is salt-sensitive crop, but if water salinity can be reduced to match its salt tolerance level or irrigation with fresh water, alfalfa can be grown in desert environment through using best soil, water and crop management practices.

Alfalfa(Medicago sativa) is the most important forage crop in the world due to its high yield, nutritional quality, high crude protein (CP) content and its adaptability to a wide range of soil and climatic conditions (Howieson and Ballard, 2004). Alfalfa is a perennial forage legume crop. It is used for grazing, hay, silage as well as green manure and cover crop, it is used less frequently as pasture. Being perennial alfalfa crop normally lives four to eight years depending upon the environment and potential of the variety. Once seedlings are established through small-seeds the plants can reach upto height of 1-2 feet along with deep root system (+2 meters) with unrestricted good soil substratum. Alfalfa initially grows slowly, after several months hard crowns are established that contain shoot buds enabling alfalfa to regrow many times after being harvested. Alfalfa when grown on soils where it is well-adapted, alfalfa is often the highest-yielding forage plant, but its primary benefit is the combination of high yield per hectare and high nutritional quality. Like other legumes, its root nodules contain bacteria *Sinorhizobiummeliloti* with the ability to fix atmospheric nitrogen, producing a high-protein feed regardless of available nitrogen in the soil. Its nitrogen-fixing ability (which increases soil nitrogen) and its use as an animal feed greatly improve agricultural efficiency. Alfalfa grows well on well-drained soils with a neutral pH of 6.8 – 7.5. Soils low in fertility should be fertilized with manure or a chemical fertilizer, but correction of pH is particularly important. Alfalfa is cut six to eight times a year. Total yields are typically around eight tons/hectare in temperate environments, but yields have been recorded up to 20 tons/ha. Yields vary with region, weather, and the crop's stage of maturity when cut. Later cuttings improve yield, but with reduced nutritional content. The agricultural farms in the UAE are mainly established on natural sandy soils or agriculture grade sandy soil is transported to new farms to develop agriculture soil layers. The sandy soil "*Typictorripsamments*" exist in two soil mineralogy classes, *mixed* and *carbonatic*, the former is more extensive in the inland and the latter towards coastal land. The soil taxonomy is briefly described below (Shahid *et al.,* 2014).

- Carbonatic, Hyperthermic Typic Torripsamments
- Mixed, Hyperthermic Typic Torripsamments

Carbonatic is the mineralogy class i.e., more than 40% $CaCO_3$ equivalents in fine earth fraction (<2mm).

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).

Typictorripsamment indicates typical desert sandy soil at soil subgroup level of USDA Soil Taxonomy (Soil Survey Staff, 2014a).

Forage situation of United Arab Emirates and agriculture intensification efforts

Forage imports and local production: UAE meets its forage needs through import and local forage production. Aldahra agriculture United Arab Emirates has the capacity to deliver about 1.1 million metric tons of forage and 58,000 metric tons of high fiber pellets to the United Arab Emirates with 70 percent supply through Mina Khalifa and 30 percent supply through Jebel Ali and Oman ports. Locally it manages 19 forage distribution sites on behalf of Abu Dhabi Food Control Authority (ADFCA) in addition to 53 warehouses with the capacity to store about 210,000 metric tons of forage. According to Hay and Forage Growers-USA, the USDA Foreign Agricultural Service (FAS) has posted U.S. hay export totals for 2017 and the total exports of alfalfa and other hay (think grass) hit 4.2 million metric tons (MT). Of the top five leading alfalfa hay-trade partners in 2017, United Arab Emirates (UAE) was the only one that imported less U.S. alfalfa than in 2016. Their import total of 0.25 million MT was down 22 percent from the previous year. In 2013, the UAE had imported 0.66 million MT, which is their historical high-water mark.

In the UAE camel and horse industry is gaining international recognition and requires quality feed to maintain their health. Importing forages has risks of quality control, suggesting to grow forages locally to control quality "*organic farming*" which conserves environment and ground water pollution. The use of biofertilizers through making use of beneficial bacteria *(Rhizobium melilotti)* and fungi (VA-mycorrhizae) could be a sound solution. These two organisms could reduce cost of fertilizers substantially, in addition to having a clean and healthy environment free of chemical pollution (Abusuwar and Mohamed, 1997). Here the question rises about the yield comparison between organic versus conventional farming using chemical fertilizers, insecticides and pesticides etc. Under present situation it is visualized that there is a need to intensify forage production "alfalfa" within existing organic farming in sandy soils of UAE. The sandy soils are plagued with agriculture limiting factors, such as these soils are infertile (low in organic matter and clay), high infiltration, low nutrient and water use efficiencies etc.. Any technology which addresses these factors in an environmental friendly and cost-effective manner should be taken as a priority. Considering these constraints and to address these issues, in the UAE an initiative is taken to intensify agriculture in general and forages in specific (Gill, 2018; Shahid *et al.,* 2015; Rao *et al.,* 2017) by using number of organic (compost, biochar) and naturally mined material "Australend Multi Mineral Rootzone Conditioner" which has shown great promise in significant water saving and intensification of barley and grass *(Paspalumvaginatum)* to over double production compared to without the use of Austra Blend Multi Mineral Root Zone Conditioner (Polyclean, 2018).

AustraBlenda water saving and forage intensification technology: AustraBlend® (ABMMRZC) is mined from Australia and is rich in Nontronite-smectitesclay mineral. Nontronite is the iron (Fe) rich member of the smectites group of clay minerals. Due to crystal imperfections and isomorphous substitution it presents high negative charges which attract positively charged nutrients (NH_4, K, Ca, Mg, Fe, Cu, Mn, Zn etc) on their negatively charged surfaces, 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. Other minerals in variable quantities are plagioclase, anorthoclase, clinopyroxene and quartz. A trial at Dubai based International Center for Biosaline Agriculture (ICBA) on the use of ABMMRZC revealed 50% guaranteed water saving in barley forage production system compared to 100% ETc water application. A trial on a substantial grassy

"*Paspalumvaginatum*" plot has revealed 50% water saving with over double the biomass production (*Paspalumvaginatum*) with the application of ABMMRZC application compared to 100% water application to similar grass plots but without ABMMRZC application (Polyclean, 2018). These two preliminary trials have shown great promise to further exploit this amendment in the UAE and other GCC countries for water saving and agricultural intensification. In addition to water saving property, it also contains macro [(Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S] and micronutrients [(Iron (Fe), Copper (Cu), Manganese (Mn), Zinc (Zn), Nickle (Ni), Cobalt (Co) and Vanadium (V)].

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%.
- 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.

The use of AustrBlend is gaining momentum in the UAE in agricultural farms and urban landscapes as well as football pitches.

Scientific classification of Alfalfa

Kingdom	Plantae
Clade	Angiosperms
Family	Fabaceae
Genus	Medicago
Species	M. sativa
Botanical name	Medicago sativa
Common name	Alfalfa, lucern

Nutritional Values of Alfalfa: Alfalfa is rich in chlorophyll, carotene, protein, calcium and other minerals, vitamins in the B group, vitamin C, vitamin D, vitamin E, and vitamin K. The sun-dried hay of alfalfa has been found to be a source of vitamin D, containing 48 ng/g (1920IU/kg) vitamin D_2 and 0.63 ng/g (25 IU/kg) vitamin D_3.

Best soil and fertility management practices for alfalfa crop: It is common practice to prepare soil well ahead of sowing of seed. Perennial weeds can be particularly competitive both during the seeding year and in subsequent years. Controlling weeds before seeding will help ensure a long-lasting and productive stand. Scout fields for perennial weeds and use appropriate control measures in the preceding crop. Use of appropriate combination of herbicide and tillage is recommended. Similarly, control perennial weeds with an effective management program before seeding alfalfa. Appropriate tillage practices are to be followed to prepare soil and eradicate weeds. Primary tillage loosens the soil and helps control perennial weeds while disking controls weed regrowth, helps level the land, and breaks up large soil clods. The final tillage should be some type of smoothing operation. The ideal soil condition for conventional seeding should be a smooth, firm, clod free soil for optimum seed placement with drills or other suitable equipment.

Fertility Management in alfalfa field: Proper fertility management is the key to optimum economic yields. Proper fertilization of alfalfa allows for good stand establishment and promotes early growth, increases yield and quality. Soil testing is the most convenient and economical method of evaluating the fertility levels of a soil and accurately assessing nutrient requirements. Most soil testing programs make recommendations for, nitrogen, phosphorus, potassium, and several of the secondary nutrients and micronutrients. Soil and plant test based fertilizers recommendations are to be used to offset nutrient requirements. There is dire need to make significant efforts to demonstrate the nutrient management in alfalfa fields. To be successful in nutrient replenishment for sustainable crop production a 4R nutrient stewardship is recommended for increased alfalfa yield (Shahid, 2018).

4R nutrient stewardship strategy

The four R Nutrient Strategy is used to offset the plant's nutrient requirement and involves:

- Right type of chemical fertilizers – (ammonium versus nitrate-based fertilizers).
- Right rate of fertilizer – based on soil testing and target yield.
- Right time of fertilizer application at the right growth stage– apply each fertilizer when the plants need specific nutrients.
- Right location of fertilizer application – apply to the root-zone area where the nutrient can best be absorbed by the plants.

The 4R Strategy looks very simple, but it is very complicated when we see from the farmers perspective. Farmersare facing many problems, such as, but not necessarily limited to, financial problem to buy fertilizers, timely availability of fertilizers when needed, fertilizer quality, how much to apply, lack of soil testing at the time of newcrop, delays of soil analyses from the laboratories, etc. The above strategy can only be effective if farmers understand the basics of 4R and implement timely on their farms. Therefore, there is big responsibility of research-extension departments to educate the farmers simple ways of 4R adoption. This requires reaching farmers and spending time to transfer 4Rs technology in an effective way to improve livelihood and food security. We need to review ourselves and see to what extent we have adopted on the farmers' fields. Not only should this but wealso check if their livelihood is improved or otherwise.

Potential of using animal manure or green waste compost to improve soil health and soil organic carbon: Manure is a complete nutrient source, containing all the major nutrients, secondary nutrients, and micronutrients. It promotes biological activity in the soil and enhances the soil physical properties. It should be noted that while manure may be beneficial to soil, applying manure on alfalfa fields can create problems, such as increasing soil salinity level and thus manure can burn leaves and reducing yield and quality. A proper quantity of manure is to be scheduled during the growth period. Other drawback of high doses of manure is increased soil nitrogen that can stimulate weeds growth. Alfalfa will use applied nitrogen but does not need it due to its ability to fix nitrogen. Therefore, careful nitrogen management will be required based on soil and plant testing and the N applied in the form of Manure and through using 4R nutrient stewardship. The effect of manures on alfalfa can be minimized using number of practices, such as but necessarily limited to, spread manure immediately after removing a cutting so manure contacts the soil instead of the foliage. This reduces the risk of salt burn and minimizes palatability problems.Take necessary action to break up large chunks of manure for uniform application.Spread manure only when soils are firm to limit soil compaction and to avoid damaging crowns.

Addition of green waste compost is another viable option to increase soil organic matter, improve fertility status (Figure 1), and improving soil structure leading to improved water and nutrient holding capacities. Compost addition is routine practice in the UAE due to sufficient local green waste availability. The green waste from urban landscapes and roadside plantation is received at the collection points and transformed to compost, baggage and sold to the farmers at the rate of 6United Arab Emirates dirhams per bag of 25 kg that is 240 AED per ton. The addition of compost at 50-80 tons per hectare is a common practice at time of sowing following by regular replenishment over crop duration.

Best seeding practices: At time of seeding adequate soil moisture enhances seed germination and establishment. Do not seed unless good soil moisture is present. It should be noted that at emergence, alfalfa is extremely cold tolerant. At the second trifoliate leaf stage, seedlings become more susceptible to cold injury. A pre-plant herbicide is usually not needed, however, post emergence herbicides can be used if severe weed problem is developed. Alfalfa needs at least 6 weeks growth after germination to survive the cold winter. Minimizing competition from weeds is critical to ensure adequate development of alfalfa. Failure to do so cuts seedling establishment and lowers yields particularly in no-till fields.

Seed inoculation with rhizobium: There is scanty rhizobium in dry sandy soils such as the UAE, it is essential to increase rhizobium quantity to allow proper nodulation for atmospheric nitrogen fixation. The inoculation can be best accomplished through seed treatment. The seed inoculation with rhizobium bacteria create nodules on alfalfa roots, allowing the bacteria to fix nitrogen where it becomes available to the plant. To ensure the presence of the needed bacteria, following should be adopted:

- While many soils contain some Rhizobium bacteria from previous alfalfa crops, not all fields have adequate numbers.
- Obtain inoculum from an authenticated commercial source, or isolate from the soil in established microbiology laboratory. In case isolation from soil is not possiblethen best choice would be to inoculate the seed using commercial inoculum available in the market.
- Check if inoculated seeds are also treated with fungicides to protect against diseases that reduce seedling emergence and kill young seedlings.
- If treatment of seeds is done at farm, then you must make sure the inoculant was stored in a cool place before and after the purchase
- Apply with an adhesive compound to attach the Rhizobia to the seedand thoroughly mix inoculum and seed before seeding in the field.
- Preferably sow the seeds with certified drill for uniform distribution of seeds and crop growth.

Using Mycorrhizae to stimulate nutrients and water availability: The mycorrhizal symbiosis is the most important ones in agriculture that has played significant role in the colonization of land by plants. The historical record shows that Vascular arbuscularmycorrhizal (VAM) interactions was evolved 400 to 450 million years ago (Smith and Read, 2008). Almost 80 % of all known land plant species form mycorrhizal interactions with ubiquitous soil fungi (Wang and Qui, 2006), such interaction is mutually beneficial and is characterized by a bidirectional exchange of resources across the mycorrhizal interface. The mycorrhizal fungus provides the host plant (such as alfalfa) with nutrients, such as phosphate and nitrogen, and increases the abiotic (drought, salinity, heavy metals) and biotic (root pathogens) stress resistance of the host. In return for their beneficial effect on nutrient uptake, the host plant transfers between 4 and 20% of its photosynthetically fixed carbon to the mycorrhizal fungus (Wright *et al.,* 1998), that is called symbiotic relationship. All AM fungi have been classified into the separate fungal phylum Glomeromycota (Schüssler*et al.,* 2001), which is composed of approximately 150 fungal species (Smith and Read, 2008) with a high genetic and functional diversity within each species. The study (Abusuwar and Ahmed, 2003) has shown rhizobium inoculation increased alfalfa fresh biomass by 42%, and VAM inoculated increased forage fresh yields by 65% over the control (without rhizobium and VAM application). Zhu *et al.* (2016) reported plants treated with rhizobia and mycorrhizae produced highest forage yield followed by where mycorrhizae or rhizobia were applied alone and control treatment.

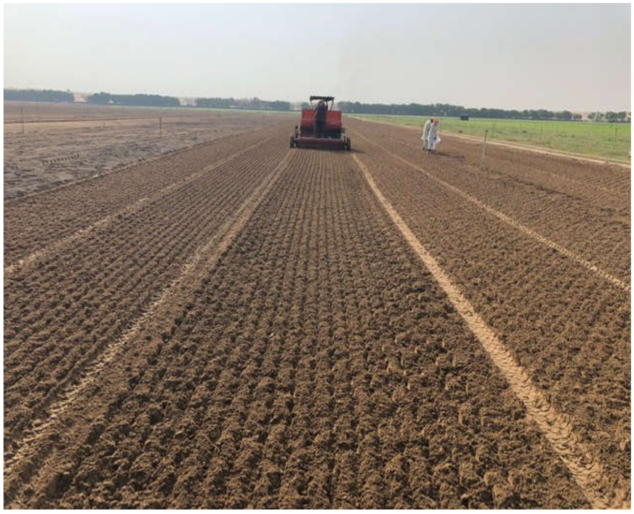
Depth of seeding in the field:Alfalfa is a small-seeded crop and correct seeding depth is very important for rapid germination and emerging from the soil. The seed should be covered with enough soil to provide moist conditions for germination while allowing the small shoot to reach the surface. Covering seed with soil also avoids seed picking by birds and hence maintains optimum seeding quantity in soil. Optimum seeding depths vary depending on soil types. Plant seed 1/4- to 1/2-inch deep on medium and heavy textured soils and 1/2- to 1-inch deep on sandy soils, such as dominant soils of the UAE and other GCC countries (KISR, 1999; EAD, 2009;EAD-MoEW, 2012; Shahid*et al.,* 2013). Shallower seeding may be used when moisture is adequate while deeper seeding should be used in drier soils. Please check the soil moisture depth before seeding.Careful irrigation is required to avoid soil crusting that prevents seeds emergence. This is true when soils are fine in texture and alfalfa is irrigated through sprinkler irrigation system, however, this is unlikely a case in sandy soils with silt plus clay less than 10 percent.

From preparation to production

Compost bags distributed in field

Compost spreaded in the field

Compost/Australend mixed and field leveled



Drilling seed in the field

Excellent alfalfa growth

Excellent alfalfa growth

Figure 1: Best soil, water and alfalfa management practices to gain highyieldand quality forage

Alfalfa field with scanty growth – needs careful management

GPS assisted science based on-site diagnostics of soil related constraints to alfalfa production

Figure 2. Poor alfalfa stand needs special attention through GPS assisted survey

Poorly managed alfalfa plot

Well managed alfalfa plot

Figure 3: Poor growth (left) improved through addressing yield inhibiting factors (right)

In-depth soil suitability assessment prior to introducing alfalfa crop

Field description of farm soils for suitability of alfalfa introduction

Figure 4. On-site investigation is pre-requisite to assure alfalfa can be introduced to new area successfully

Box 1: Proposed model of activities and deliverable for forage intensification

• The preliminary information of existing alfalfa fields to diagnose constraints to full potential of alfalfa production	• Preparation of comprehensive questionnaires including information about farm resources, crops, fertilizer use, varieties use, growth potential and marketing opportunities
• Science based diagnostics of alfalfa fields to gain about constraints farmers are facing to have potential of their farms	• Interviews of farmers to have firsthand information to set up best management plan for alfalfa production
• Mitigation measures – recommendations to enhance alfalfa production	• Package of recommendations for implementation at farmers' fields to enhance their farm productivity
• Training farmers and farming staff	• Farm staff and labors trained on various (soil, water, crop, nutrients, weeds etc) aspects of alfalfa production
• Knowledge sharing	• Distribution of flyers, brochures and published literature to aware the farmers with the latest best management practices.

Constraints and viable options to improve alfalfa production: Alfalfa plant exhibits auto-toxicity which means it is difficult for alfalfa seed to grow in existing stands of alfalfa. Therefore, alfalfa fields are recommended to be rotated with other species (other potential crops, like maize, sorghum, pearl millet, grasses etc) before reseeding. Low seed rates used, usually a seeding rate of 13 – 20 kg/hectare is recommended, with differences based upon region, soil type, and seeding method. Harvesting the alfalfa by mowing the entire crop area destroys the soil biology, but this can be avoided by mowing in strips so that part of the growth remains. Wet soils create conditions suitable for diseases that may kill seedlings, reduce forage yield, and kill established plants. High pH of soil disturb the nutritional balance due to precipitation of phosphorous and micronutrients. Insufficient inoculum in soil reduces nodulation and nitrogen fixation. Another limitation to crop growth is poor drainage due to hard pan within potential rooting zone (1 m) of alfalfa. Poor soil drainage also reduces the movement of soil oxygen to roots while uneven soil leads to low spots where water stands and create patchy water logging. The weeds if not controlled before seeding, these weeds may re-establish faster than the new alfalfa seedlings and reduce stand density. Alfalfa is classified as sensitive to salt tolerant (threshold soil salinity-ECe 2 dS/m) and hence if irrigated with saline-brackish water the yield can be reduced significantly. The poor growth of alfalfa can be managed by GPS assisted survey of the farms and developing best management practices to overcome the yield limiting constraints (Figure 2). Once the yield inhibiting constraints are addressed through best management practices the poor stand can be improved for higher production (Figure 3).

Autotoxicity in Alfalfa and remediation: Alfalfa plants produce toxins that can reduce germination and growth of new alfalfa seedlings. This phenomenon is known as *autotoxicity*. The extent of the toxin's influence increases with the age and density of the previous stand and the amount of residue incorporated prior to seeding. The autotoxic compounds are water soluble and are concentrated mainly in the leaves. The compounds impair development of the seedling taproot by causing the root tips to swell and by reducing the number of root hairs. This limits the ability of the seedling to take up water and nutrients and increases the plant's susceptibility to other stress factors. Surviving plants will be stunted and continue to yield less in subsequent years. A waiting period after destroying the old stand is necessary to allow the toxic compounds to degrade or move out of the rootzone of the new seedlings. Weather conditions influence the speed with which the toxins are removed. Breakdown is more rapid under warm, moist soil conditions. The autotoxic compounds are removed more rapidly from sandy than heavier textured soils, such as dominant sandy soils "Entisols" of the United Arab Emirates (Shahid *et al.,* 2013). However, while the compounds are present, the effect on root growth is much more severe in sandy soils. Ideally, grow a different crop for one season after plowing down or chemically killing a 2-year or older stand before seeding alfalfa again in the same field. This is the best and the safest way to manage new seeding of alfalfa.

Managing harvesting of alfalfa: When alfalfa is to be used as hay, it is usually cut and baled that is easy to store, transport and feed. Ideally, the first cutting should be taken at the bud stage, and the subsequent cuttings just as the field is beginning to flower, or one-tenth bloom because carbohydrates are at their highest. When using farm equipment rather than hand-harvesting, a swather cuts the alfalfa and arranges it in windrows. In areas where the alfalfa does not immediately dry out on its own, a machine known as a mower-conditioner is used to cut the hay. When used as feed for dairy cattle, alfalfa is often made into haylage by a process known as ensiling. Rather than being dried to make dry hay, the alfalfa is chopped finely and fermented in silos, trenches, or bags, where the oxygen supply can be limited to promote fermentation. The anaerobic fermentation of alfalfa allows it to retain high nutrient levels similar to those of fresh forage, and is also more palatable to dairy cattle than dry hay. In many cases, alfalfa silage is inoculated with different strains of microorganisms to improve the fermentation quality and aerobic stability of the silage.

Mitigation to improve alfalfa yield: The low yield of alfalfa can be improved by using appropriate mitigation practices, 1) select high yielding varieties with high levels of resistance to insects and diseases, 2) soils should be healthy, deep enough to have adequate water-holding capacity, 3) this great rooting depth gives alfalfa excellent drought tolerance, 4) integrated nutrient management provides balanced nutrition for healthy growth, 5) irrigation management to offset crop requirement based on ETc and leaching requirement (LR), 6) fields should be free from herbicide carryover that may affect growth of the new alfalfa and 6) autotoxication in alfalfa fields should be dealt with carefully.

Irrigation management in alfalfa fields: Improper irrigation limits alfalfa yields more often than any other management factor. Alfalfa crop is salt sensitive; therefore, irrigation water salinity is to be checked carefully and necessary action taken to manage water/soil salinity in alfalfa fields. Determine crop water requirement based on crop evapotranspiration (ETc), the combined evaporated water from soil and plant surfaces. Irrigation scheduling is best accomplished by the water balance method, in which calculations of water inputs equal outputs, can be used to estimate the soil moisture condition. Determine ETc per day (based on evaporation and crop water coefficient) and schedule irrigation rate and timing per irrigation. Alfalfa yield is directly related to ETc and the efficiency of water use is the highest when the water supplied to plants approximates ETc and leaching requirement to maintain soluble salts in the root zone to an acceptable level. Irrigation to be scheduled to have enough moisture in the rootzone before the period of peak crop water use in the day.

Water dynamics in sandy soils of UAE: Sandy soils of UAE, have following properties that may be watched carefully to achieve optimum alfalfa production. Sandy soils have low water and nutrient holding capacity and therefore highly vulnerable to higher water infiltration rates leading to nutrient losses and groundwater contamination. Plant stress can occur when available soil moisture falls below 50% in the effective root zone and the crop yield decreases, this lost yield cannot be "made up" by irrigating more than necessary following the stress. Therefore maintaining soil moisture at sufficient level "*field capacity*" is must for seeds to germinate and emerge and for optimum forage production. Sprinkler irrigation is recommended for alfalfa with the condition that the field is not sloppy, which may cause erosion, and soil is not heavy that may cause crusting. Also the water salinity is not high to do foliar damage "*leaf necrosis*", however this is not the case when irrigation is done with low level of water salinity or fresh water. Stop irrigation atleast two days from harvesting, to facilitate harvesting.

Effect of weeds on alfalfa production: The most important factor in weed management is to establish and maintain a vigorous alfalfa crop. Most alfalfa stands are left in production for several years. The absence of tillage during the life of the stand naturally favors invasion by perennial weeds. Thorough tillage helps uproot existing annual weeds and sets back established perennial weeds. It is very important to eliminate perennials before establishing alfalfa. Weeds reduce alfalfa production during establishment by competing with and choking out young alfalfa seedlings. Weeds also invade established alfalfa fields and reduce forage quality and alfalfa yield. Effective weed control begins before seeding and continues throughout the life of the stand. Proper soil fertility and pH, seedbed preparation, varietal selection, and appropriate cutting schedules cannot be overemphasized to prevent weed encroachment. If using herbicide, remember that application timing and rates vary.

Basic requirements to introduce alfalfa crop in new areas: The long-term objective and goal of introducing alfalfa crop in new agriculture areas is usually to increase forage production in the region, or to enhance alfalfa production of existing alfalfa stand. This is only possible through science based diagnostics (Figure 4, Box 1) and using proved and tested off-the shelf technologies. It is recommended to achieve the objective by following the basic points. Field assessment of existing alfalfa fields to diagnose the constraints to biomass production and developing best management practices formulation. Such information can be collected through organized questionnaires following by interviews of the potential farming community and visiting alfalfa fields. The information so collected should be synthesized to identify yield limiting constraints. Science based diagnostics of existing alfalfa farms through collecting soil and water samples and laboratory analyses help understand soil physical, chemical and fertility status leading to develop strategy to improve soil health through proven and tested technologies and farmers training.

Science based diagnostics of existing alfalfa fields and mitigation measures to intensify alfalfa production: Conduct reconnaissance surveys of existing alfalfa fields (visual farms survey identified yield reduction constraints including soil, water, weeds, crop, insects, pests etc). Observation of nodulation (number and sizes) on alfalfa plants roots. Determination of soil depth through standard soil auguring and collection of soil samples from various depths (0-50, 50-100 & 100-150 cm) and laboratory testing of soil samples – [pHs, ECe (salinity), soil texture, gravels, $CaCO_3$, gypsum, soil sodicity, organic matter, NPK] using standard procedure (Soil Survey Staff 2014b). Toxic substances – residues of herbicides, fungicides, pesticides, autotoxication. Based on the results from questionnaire and field survey recommendations can be formulated to enhance alfalfa production, such as, but not necessarily limited to: improving inoculum in the root zone, seed treatment pre-sowing, integrated nutrient management using 4Rs stewardship (Right – source, time, rates & place), weeds management, improving soil health using organic and inorganic amendments (compost, inorganic soil conditioners, manure etc). Reducing residual effects of herbicides, weedicides, fungicides, toxicity, exploring high yielding varieties of alfalfa and crop rotation to reduce toxic effect of alfalfa. Based on the preliminary information, reconnaissance survey, synthesis of questionnaires, package of technologies should be formulated and tested in the field through establishing demonstration plots and by including combination of mitigation measured, 1) preparation of field based on soil health improvement measures (using various combinations of compost, manures, biochar and inorganic soil conditioners, 2) inoculation of alfalfa fields and seed treatment, sowing of high yielding alfalfa varieties, integrated nutrient management (INM) – nutrient scheduling, irrigation management based on crop water requirements (ETc), weeds eradication, harvesting of alfalfa and determination of fresh biomass, baling alfalfa hay and marketing plan to reach to the potential farming community.

Capacity development and knowledge sharing: It is true that technologies have been established and many research papers are published in high impact factor journals, but many times these high quality research remains in the hands of scientists and hardly reaches to farmers. It is therefore essential to transfer proved and tested technologies to the farming communities before these technologies losses their credibility. This can be achieved through number of ways, through establishing demonstration plots and organizing field days where farmers have to witness the performance of various technology for their adoption, distribution of flyers and brochures and through organized training on soil, water and crops management.

Conclusions and recommendations

From this descriptive paper on alfalfa forage crop, it is concluded that regardless of UAE located in dry lands and have water scarcity issue, the alfalfa can be grown in the UAE with a purpose, such as to achieve high fodder quality to feed camels and horses through organic farming, saving financial resources and ready availability of fresh fodder without making hay. The UAE and other GCC country soils are dominantly sandy and are poor in soil fertility (lack of organic matter and clay content) and therefore to keep these sandy soils healthy for good forage production green waste compost and mined clay rich material “Austrablend” may be used to compensate the quality of non-fertile sandy soil. Where the soil and water sources are saline, alfalfa has to be selected carefully keeping in mind that it may loss significant yield based on combined effects of both soil and water salinity. To keep the soils healthy it is recommended to use 4R nutrient stewardship (Right-source, type, rate and location) to replenish nutrients in alfalfa fields, as well as seed inoculation, use of mycorrhizae. There is a need to train the farmers and other staff on the best management practices of soil, water, crop management to achieve high benefits from the farms.

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