The influence of Diatomaceous Earth (DE), (Agripower Silica as composed of the skeletal remains (diatoms) of freshwater algae (species *Melosira Granulata*)) on the growth and development of Date Palms, grown under moderately saline irrigation water in the Riverland of South Australia.

Shane Phillips
Research Agronomist Landmark Australia
Shane.phillips@landmark.com.au

ABSTRACT

The South Australian Mallee region is characterised by alkaline soils. The site where the date palms are grown in this trial are from a moderately saline backwater of the Murray River where irrigation EC can be as high as 2600Ec Ds/m. Published research has indicated that silica is a very important nutrient in date palm production and that reduction in plant silica levels resulted in slower growth rates . The aim of this project was to investigate the role that increasing silica applications (silica as diatoms of Melostra granulata) would have on the growth and development of young date palms and if previously published research could be replicated under Australian growing conditions. Applications of the product were applied to Barhee date palms at the rate of 2, 4 and 8kg per palm tree in October 2012. Tissue test data revealed less Si where the Agripower Si product had been applied irrespective of treatment application in comparison to the control. It is proposed that this decrease in plant tissue levels is a function of a growth dilution effect. What was noticeable was that where the product was applied mean frond and leaflet length were significantly increased in comparison to untreated control palms. Mean leaflet length increased from 37.04cm Control to 40.13cm (2kg/palm), 41.04cm (4kg/palm) and 41.58cm (8kg/palm) and mean frond length from 2.52m (Control), 2.64m (2kg/palm), 2.67m (4kg/palm) and 2.68kg (8kg/palm). The significance of this data was that treated palms were visibly larger than untreated control palms within the first growing season that

the product was applied. Further applications of Si were made in September 2013 for continuation of assessment of long term implications of Si applications as Agripower DE on the growth and production of date palms in this region.

Acknowledgements

This work was generously funded and supported by Agripower Australia and without this support the trial would not have come into fruition. Special thanks to Andrew McHugh and Regan Crooks from Agripower for technical input and support over the trial. To Dave and Anita Reilly whose property the trial has been conducted on and who have been pioneers in the revitalisation of the date industry in Australia, a special thanks.

INTRODUCTION

Date palms have been grown in Australia since the late 1800's yet it is has only been in relatively recent times has the crop been looked as a potentially significant horticultural crop in Australia. As a result the technical understanding of production and suitable varieties relies heavily on the experience of those in the Northern Hemisphere and extension and application of this data into Australian growing conditions. As a result the agronomic knowledge of specific issues in managing Date Palms in Australia, and the variance of application of overseas data for Australian growing conditions are still very much based on learning to adapt overseas information. This has meant determining the significance of overseas data and screening its' application to Australian growing conditions.

Matichenkov and Bocharnikova (2006) noted that historically date palms grew in oases that were related to a geological depression and artesian waters. These regions were characterised by silicon rich waters due to the concentration of mobile silica in the geological depression zones. Their conclusion was that date palms require high amounts of silica and in further studies determined that plants irrigated with desalinated water were deficient in silica nutrition. Fruit analysis determined that the maximum total of Si could be found in the epidermal tissue of the clingstone (0.81-1.51% from dry mass) and lower amounts in the fruit stem, clingstone core and pulp. They also noted that as Si levels dropped so did fruit sugar content as did the growth of young palms. With increasing plantations of date palms grown on water significantly different from the composition of the oases where they were originally grown, Si could play a significant role in plant nutrition.

From being a plant found around oases throughout the Middle East today the date palm is commercially grown on reclaimed, desalinated, bore and river water across the globe. Therefore the chemical composition of the water is significantly different to that which the plant has evolved on and this variance could create issues in the growth and development of date palms in a number of environments.

Silica is such a large percentage of the mineral matter of the earth's crust by weight (27.7%) (Hausenbuiller,(1985). With such a high percentage of silica in the earth's crust, the role of silica in plant nutrition has been regarded more widely as a curiosity to researchers; at a field level applications of silica for crop nutritional purposes are largely ignored. However in recent years there has been a renewed interest in the potential role of Silica in plant nutrition.

Silica has been well documented as a plant nutrient and oats can contain 1% Si as dry material (Leeper 1967). This is significantly more than K in dry matter at 0.6%. Leeper notes in his book 'Introduction to Soil Science' which has been a foundation book of young soil scientists since it was first published in 1948 and edited over the next 30 years was that a soil with a good supply of primary silicates can remain chemically rich over many years of cropping. An interesting note in this book on page 170 states that 'The conclusion is rather that the primary minerals can guarantee the chemical fertility. The experiment is so striking that it is strange that this section of the knowledge of soils has been so neglected. The experiment also shows the powerful weathering properties of acid clay.' Is it possible that with Si being such an abundant element that it has been traditionally regarded as an element that does not gain a lot of attention in traditional plant nutritional management plans? The documented variance in Si levels between different plant species also makes conventional recommendations more difficult than with nutrients such N, P and K.

It is also interesting to note that aluminium toxicity in soils while being dependant on solubility at low soil pH but also on the nature of the clay soil that is being acidified. It has been noted that the sesquioxidic clays provide more aluminium than the siliceous clays and hence a higher degree of toxicity under acidifying conditions. The significance of this should not be lost in the potential of Si to alleviate Al toxicity under acidifying soil conditions. With increasing use of recycled water and acidification of drip zones issues around aluminium toxicity and potential management considerations may need to be considered. It is in these areas that the use of silica may be beneficial.

Leeper further notes that the monocots absorb silicon in large amounts with up to half of the ash being Silica dioxide. Si has been documented in increasing resistance to pathogens such as blast in rice(Datnoff et al 1997) and powdery mildew in cucumber (Miyake and Takahashi 1982).Si has also been found to prevent lodging in rice and it is perhaps this role that has the greatest application in world wide applications.

Jones and Handreck (1967) note that importance that Si plays in alleviating Mn toxicity. This may play an important role where acidic soil conditions are required but Mn toxicity symptoms are an issue. Applications of Si may be useful in reducing plant available Mn and reducing toxicity risks. West (et al) 2007, note that while Si is not noted as an essential mineral element for plant growth it has many beneficial effects on plant performance. This stems from increased resistance to fungal diseases, improved mechanical stability of leaf and blades and improved water stress. They further note that there is great variation in uptake of Si in plant species and that it is not unrealistic to assume that responses to soil applied Si in one species do not mean that similar responses would be expected in other species.

Ahmed et al (2012) note that Si is able to help plants withstand the adverse effects of drought and improve plant water use efficiency. It is proposed that the mechanisms to improved salinity tolerance in plants as a result of Si were increased photosynthetic activity and ultra-structure of leaf organelles. In their work on drought tolerance of wheat they determined that while a single trait cannot make a plant resistant to water stress, the beneficial effects that Si would play for screening drought resistant genotypes. In a world facing heat waves and shortages of irrigation water this work may prove to be significant in our application of Si to agricultural crops

Silicon (Si) plays a significant role in imparting biotic and abiotic stress resistance (Ma et al, 1989) and enhancing growth and yield, especially in accumulator species (Street-Perrot and Barker, 2008). While there have been numerous studies, some specific examples include Si increasing resistance to pathogens such as blast in rice (Datnoff et al, 1997) and powdery mildew in cucumber (Miyake and Takahashi, 1982). Si has been found to prevent lodging in rice and it is perhaps this role that has the greatest current application in worldwide applications.

Si deficiency in soil is now recognized as being a limiting factor for crop production, particularly in soils that are deemed to be low or limiting in plant available Si and for known Si-accumulating plants (Ma and Takahashi, 2002).

The plant available Si of a soil is reliably measured through an extraction procedure using a calcium chloride solution. Calcium chloride extracts the easily soluble Si and has been shown to correlate well with yield increases (Berthelsen et al, 2001; Haysom and Chapman, 1975). Critical limits and ranges have been reported (Narayanaswamy and Prakash, 2009) for the $CaCl_2$ extractant method on soils. They determined that 43ppm was the critical soil level for this extraction method.

The aim of this trial is to investigate the potential use of Si in the mallee soils used for date palm production and if published research work on the role of Si in date palm growth can be extended into Australian growing environments.

MATERIALS AND METHODS

Site

The date palm trial site is located at the property of Dave and Anita Reilly in the Gurra region of the Riverland in South Australia. The property is irrigated out of the Gurra Lake which is a backwater from the Murray River. Due to its location water is significantly more saline than irrigation water taken straight out of the river system. Irrigation water has been as high as 5000EC dS/m but with the breaking of the drought and increased flows in the river system, irrigation water salinity levels have dropped to between 1200-1800 EC dS/m in recent seasons.

The local climate is associated with hot dry summers and mild winters with rainfall averaging 245mm/pa. Due to the nature of storm events, rainfall is highly variable and over the past 10 years annual rainfall events have ranged from 83-435mm/pa.

The soil at this property is a calcareous sandy clay loam with clay subsoils at depth. Irrigation is undertaken with drip irrigation with drippers based around each palm. Dripper output is 25L/hr with 3 drippers per palm. The large output drippers enable soils to be filled to field capacity and manage high algal content associated with water in this area. The larger outputs also enable better manage for the high colloidal content of the irrigation water.

Treatments

Applications of the Agripower Si material were banded around the base of each *Barhee* date palm at rates of 2, 4 and 8kg per palm. As the site is used for commercial production full rows of each treatment were implemented for incorporation with minimal disruption into the overall farm management operation.

Agripower Si was applied on the 14/9/12 and again on the 4/9/13. Measurements of soil nutrient status, tissue tests and plant phenology were undertaken over the 2 growing seasons.

RESULTS

A complete analysis of the Agripower Si sample what was to be applied in the trial site and a pre-treatment soil test were undertaken to determine starting point soil fertility and also the chemical composition of the Si to be applied in this soil test

Table 1: Technical Information on Product: AgriPower Silica Raw Material:
Diatomite A typical analysis of this mineral is given below:

Typical Analysis	
Calcium	1.5%
Iron	5.9%
Magnesium	1.05%
Potassium	0.07%
Zinc	19ppm
CEC	52cmol/kg
Soluble Si	1,212ppm
pH	8.1

Table 2: Soil test results from trial site, prior to application of AgriPower Silica

Element	Result	Units
pH (1:5)	8.7	
Electrical Conductivity (1:5)	0.16	mS/cm
Organic Carbon	0.3	%
Nitrate – N	4	mg/kg
Phosphorous (BSES)	41	mg/kg
Phosphorous (Colwell)	18	mg/kg
Phosphorous (Olsen)	11	mg/kg
Potassium (exchangeable)	431	mg/kg
Calcium (exchangeable)	4858	mg/kg
Magnesium (exchangeable)	302	mg/kg
Cation exchange Capacity	28	cmol/kg
Sulphate – S	42	mg/kg
Chloride – Cl	31	mg/kg
Boron	0.58	mg/kg
Zinc (DTPA)	0.32	mg/kg
Copper (DTPA)	0.62	mg/kg
Iron (DTPA)	2.42	mg/kg
Manganese (DTPA)	0.68	mg/kg
K Cation	3.93	%
Ca Cation	86	%
Mg Cation	9	%
ESP	0.74	%

Element	Result	Units
K:Mg	0.44	Ratio
Ca:Mg	9.6	Ratio
C:N	0.08	
Soluble Silica	52	Ppm

Comments on soil results

The alkaline nature of soil in this sample is typical of the region. The soil has high levels of underlying limestone of variable particle size. Soil phosphorus levels are low and potassium levels are high which is typical of most soils in this region. The hot dry conditions and low rainfall results in very low levels of organic carbon.

The soluble silica was measured using the calcium chloride extraction method and found to be 52ppm suggesting that this soil type would be responsive to applications of silica.

The property is devoted to the production of organic dates so the lower nutrient levels in comparison to more intensive systems in line with soil nutrient levels in this region. The regional clay loam based soils are traditionally high in potassium and trace element levels (low) are normal for this soil type.

Plant phenology data

Fronds and leaflets were measured from the youngest mature frond to determine any potential variance between treatments. Measurements were taken twice over the growing season with individual data collated and compared between and within treatments for analysis of variance.

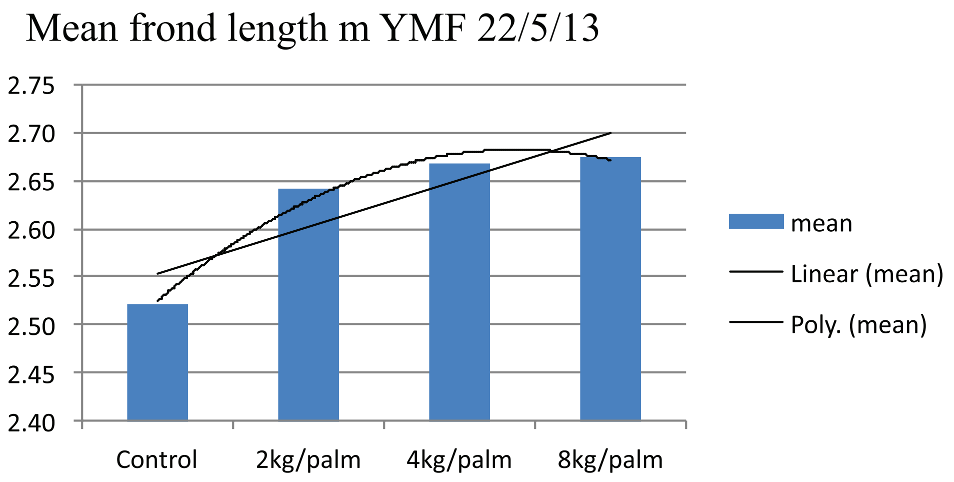
Table 3: Frond length sample dates 22/5/13 and 18/10/13 - **22/5/13**

	Control	2kg/palm	4kg/palm	8kg/palm
	2.52	2.61	2.71	2.68
	2.53	2.63	2.69	2.63
	2.53	2.59	2.69	2.85
	2.49	2.6	2.79	2.75
	2.53	2.6	2.67	2.63
	2.49	2.62	2.75	2.64
	2.53	2.67	2.61	2.7
	2.63	2.89	2.61	2.6
	2.51	2.52	2.67	2.59
	2.49	2.65	2.7	2.86
	2.52	2.64	2.47	2.81
	2.57	2.63	2.47	2.51
	2.5	2.68	2.63	2.53
	2.52		2.88	
	2.46			
	Control	**2kg/palm**	**4kg/palm**	**8kg/palm**
Mean	2.52	2.64	2.67	2.68
STDEV	0.04	0.08	0.11	0.11
Average deviation	0.02	0.05	0.07	0.09

18/10/13

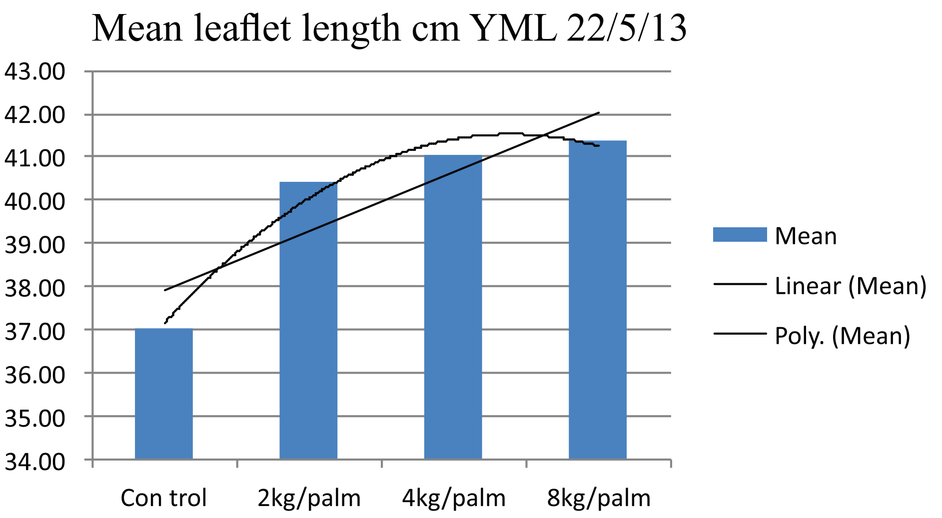
	Control	2kg/palm	4kg/palm	8kg/palm
	2.78	2.65	2.9	2.78
	2.51	2.75	2.84	2.78
	2.47	2.67	2.69	2.7
	2.6	2.78	2.64	2.56
	2.47	2.7	2.7	2.7
	2.36	2.71	2.82	2.86
	2.47	2.67	2.63	2.68
	2.6	2.67	2.75	2.66
	2.42	2.8	2.75	2.55
	2.39	2.66	2.75	2.74
	2.39	2.57	2.56	2.82
	2.43	2.55	2.57	2.64
	2.42	2.68	2.71	2.53
	Control	2kg/palm	4kg/palm	8kg/palm
Mean	2.49	2.68	2.72	2.69
STDEV	0.12	0.07	0.10	0.10
Average deviation	0.02	0.05	0.07	0.08

The tabled data above highlights quite considerable differences in mean frond length between the control and rows where Agripower Si has been applied. The increase in frond length in the treated palms was maintained throughout the current growing season and that untreated palms did not recover in average frond growth rates over the current growing season. The graphs below represent this data in a more visual format.



Graph 1: Mean frond length youngest mature frond (YMF) in metres 22/5/13

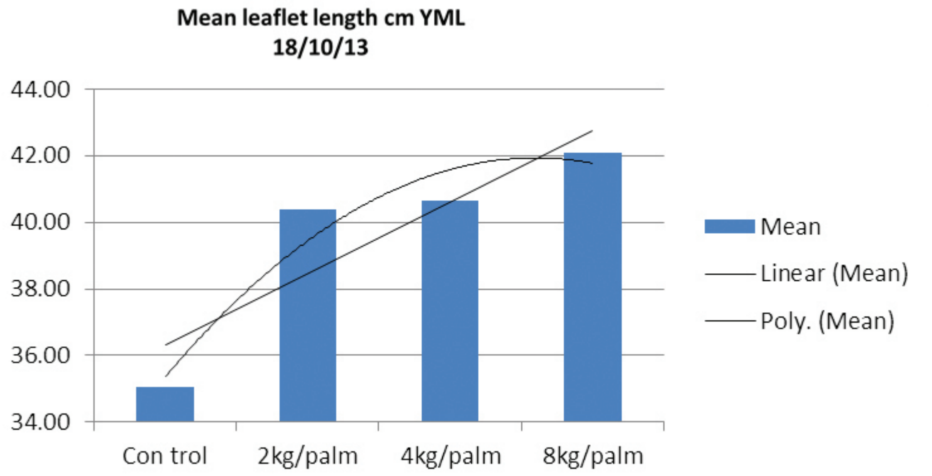
Mean frond length can be seen to be greater in the treated over the untreated palms within the same planted area in the trial block. By applying a polynomial trend line to the data the aim was to determine potential limiting rates to Si application as influencing frond length.



Graph 2: Mean leaflet length from the mid leaflet of the youngest mature leaflet (YML). 22/5/13

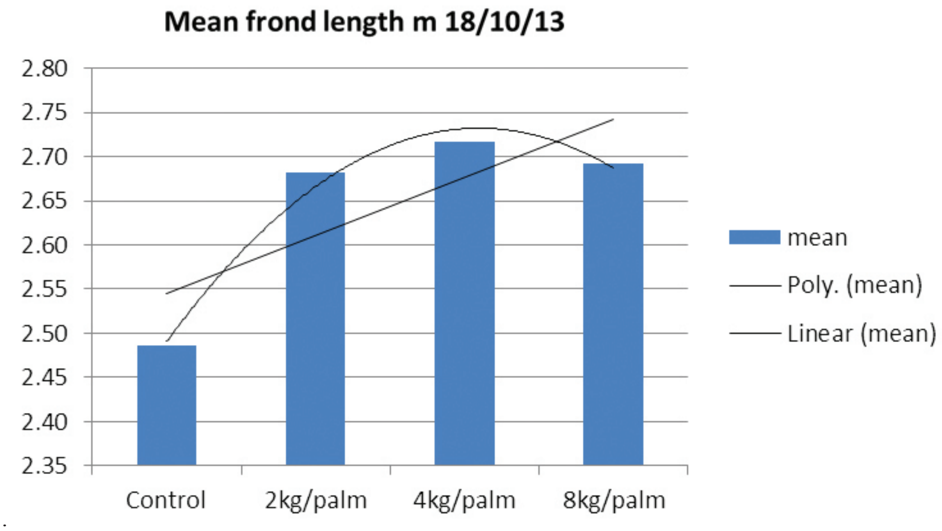
Leaflet length and frond length are in line with each other and would suggest that leaflet length correlated to frond length in a date palm.

Further frond and leaflet samples were taken on the 18/10/13. The aim of these measurements was to see if any correction or changes to leaflet and frond length had occurred in the 5 months from the original sampling date.



Graph 3: Mean Leaflet Length 18/10/13

Data from the 18/5/13 is in line with sample data from the 22/5/13. There has been minimal change to leaflet length from the mid part of the frond since the original sampling.



Graph 4: Mean frond length 18/10/13

Data from the 2 sampling dates indicate that growth response to applications of the Agricpower Si product occur early in the development phase of the frond and leaflets and that this response is held over time in the plant. This would suggest that the impact of the vegetative response is made earlier in the growth phase and that relatively small applications of Agripower Si have resulted in quite significant increases in vegetative growth.

Tissue test results

Tissue analysis was conducted on both the 14/11/12 and 20/9/13 to determine if there were any significant differences in plant nutrient levels between treated and untreated palms. Leaflets were taken from each treated palm to form a composite tissue sample for analysis.

Table 4: Dried tissues analysis 14/11/12

Nutrient	Control	2kg Palm	4kg Palm	8 Kg/Palm
B ppm	16	15	15	14
Ca %	0.27	0.27	0.21	0.21
Cu ppm	118	108	89.5	61.8
Fe ppm	55	63	50	50
K %	2.02	2.02	2.06	1.91
Mg %	0.21	0.22	0.21	0.2
Mn ppm	25	26	23	23
Mo ppm	0.01	0.01	0.01	0.01
N %	1.62	1.49	1.4	1.46
NO3-N ppm	7	9	4	9
Na %	0.05	0.05	0.05	0.05
P %	0.14	0.14	0.16	0.14

Nutrient	Control	2kg Palm	4kg Palm	8 Kg/Palm
S %	0.15	0.16	0.14	0.14
Si mg/kg	1387	689	698	692
Zn ppm	15	15	15	14

Sample Date 20/9/13

Nutrient	Control	2kg Palm	4kg Palm	8 Kg/Palm
B ppm	42	37	46	43
Ca %	1.01	0.95	1.08	0.99
Cu ppm	13.4	13.7	17.6	14.9
Fe ppm	70	70	88	69
K %	0.57	0.73	0.59	0.63
Mg %	0.39	0.37	0.4	0.37
Mn ppm	40	43	46	51
Mo ppm	0.39	0.40	0.36	0.38
N %	1.72	1.73	1.75	1.77
NO3-N ppm	20	21	18	18
Na %	0.05	0.05	0.05	0.05
P %	0.15	0.16	0.15	0.15
S %	0.25	0.16	0.24	0.27
Si mg/kg	3374	3015	3045	2642
Zn ppm	18	17	15	15

The only consistent data in both sets of tissue data is that the more Si that has been added to the plant, the lower the amount in leaflet tissue analysis. It is assumed that the reason for this variance is due to a dilution factor in the tissue as a function of increased vegetative growth. It is also possible due the physiology of the date palm other parts of the plant may be a major sink for Si and that tissue analysis while reflecting Si (and other nutrient levels at a point in time), do not reflect total nutrient distribution within the plant.

From observation of the data, Date Palms can be seen to have a high leaflet content of Si to the extent that this nutrient could be regarded as one of the major plant nutrients for this species. These are in line with the observations made by Matichenkov and Bocharnikova (2006).

SUMMARY AND CONCLUSION

A field level study into plant nutrition effects is not an exact science since it is difficult to achieve perfect replicas of the same plant for the study in a field situation. Small variations in soil type and hydraulic distribution of water within the root zone can have significant physical effects on plant growth as well as genetic variance between plants of the same variety. However in spite of this natural variance applications of Silica have resulted in visually significant and measurable changes in plant growth and development. This is in line with published data showing the significance of silica on the growth and development of date palms in other parts of the world.

While the length of this research has not been able to quantify the impact of Silica on fruit loads in date palms in terms of increased water use efficiency and drought tolerance, the increased growth achieved through applications of

Agripower Si in vegetative mass is encouraging.

References

Ahmed M., Asif M., Goyal A. 2012. Silicon the non-essential beneficial plant nutrient to enhanced drought tolerance in wheat p31-48. In: Crop Plant A. Goyal Intech Croatia

Jones L.H.P., Handreck K.A.1967. Silica in soils, plants and animals p107-145. In: A.G.Norman Advances in Agronomy Academic Press Inc

Matichenkov V.V., Bocharnikova E.A.2006. Prospective of Silicon Fertilization for Date Palms 3rd International Date Palm Conference February 19-21 2006 Abu Dhabi

Wiese H.,Nikolic M.,Romheld V.2007. Silicon in plant nutrition p33-47. In: The apoplast of higher plants - compartment of storage transport and reactions. Springer

Datnoff L,E., Deren C.W., Snyder G.H, 1997. Silicon fertilization for disease management of rice in Florida. Crop Protection 16, p 525-531

Hausenbuiller R.L.1985. Soil Science Principles and Practice. Wm C. Brown Publishers Iowa

Leeper, G.W.(1967). Introduction to Soil Science Melbourne University Press

Ma J, Nishimara K, Takahashi E. 1989. Effect of silicon on the growth of rice plants at different growth days. Soil Sci. Plant. Nutr. 35:347-356.

Matichenkov V.V., Bocharnikova E.A.2006. Prospective of Silicon Fertilization for Date Palm. 3rd International Date Palm Conference 19-21/2/06 Abu Dhabi

Ma J, Nishimara K, Takahashi E. 1989. Effect of silicon on the growth of rice plants at different growth days. Soil Sci. Plant. Nutr. 35:347-356.

Ma, J.F. and Takahashi, E, 2002, “Silicon uptake and accumulation in higher plants”, Soil, Fertiliser and Plant Silicon Research, Vol 11, no.8

Street-Perrott and Barker, 2008, “Biogenic silica: a neglected component of the coupled global continental biogeochemical cycles of carbon and silicon”, Earth Surf. Process. Landforms 33, 1436–1457.