MOLLIFICATION OF CADMIUM TOXICITY IN POTATO TUBER GROWING IN TREATED SOIL BY USING MORINGA SEED EXTRACT AND SILICON

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CERTIFICATE

This is to certify that the thesis entitled ***"MOLLIFICATION OF CADMIUM TOXICITY IN POTATO TUBER GROWING IN TREATED SOIL BY USING MORINGA SEED EXTRACT AND SILICON"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY****, embodies the results of a piece of bona fide research work carried out by* ***SHARMIN AKTER, Reg. No. 13-05732*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I, further, certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

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TO

MY BELOVED

PARENTS

LIST OF ACRONYMS

Acronyms	Full word
Agril.	Agricultural
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Bull.	Bulletin
Cd	Cadmium
cm	Centimeter
Cu	Copper
CV	Coefficient of Variation
DAS	Days After Storage
Env.	Environmen
et al.	And others (*et alibi*)
FAO	Food and Agriculture organization
Fe	Iron
g	Gram
i.e.	Id est, in other words
J.	Journal
pH	Hydrogen ion concentration
LSD	Least Significance Difference
Pb	Lead
MSE	Moringa Seed Extract
MSI	Membrane Stability Index
MT	Matric Ton
NS	Non-Significant
%	Percent
Pharmacol	Pharmacology
Photosynth	Photosynthesis
Physiol	Physiology
Regul	Regulation
Res	Research
ROS	Reactive Oxygen Species
RWC	Relative Water Content
SAU	Sher-e- Bangla Agricultural University
Sci	*Science*
Sp. gravity	Specific gravity
TCRC	Tuber Crop Research Centre
TSP	Total Soluble Solid
viz.	videlicet (L.),Namely

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The Author

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ABSTRACT

A pot experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November 2018 to February 2019, to mollify the toxic effect of Cd on potato (*Solanum tuberosum* L.) tuber by using Moringa Seed Extract (MSE) and Silicon (as Sodium Silicate, Si). The experiment consisted of 2 factors with four replications: Factor A: Levels Moringa Seed Extract (MSE) as- M_0: Control (0% solution in 50 ml water kg^{-1} soil), M_1: 3% solution in 50 ml water kg^{-1} soil, M_2: 6% solution in 50 ml water kg^{-1} soil and M_3: 9% solution in 50 ml water kg^{-1} soil; Factor B :Levels of Si as Sodium Silicate (Si) as- Si_0: Control (0 $mgkg^{-1}$ soil), Si_1: 100 mg kg^{-1} soil, Si_2: 200 mg kg^{-1} soil and Si_3: 300 mg kg^{-1} soil. The result revealed that all growth and yield contributing parameters positively responded with increasing MSE levels except days to emergence and days to maturity. Quality parameters like tuber peel and flesh also increased gradually with the increasing levels of this treatment. The effect of Si levels were also significant on growth, yield and quality contributing parameters viz., quality of potato peel and flesh, dry matter content, specific gravity of tuber were increased gradually. Yield of potato increased with increasing Si levels. Cd content of potato tuber flesh and peel gradually decreased with increasing both MSE and Si levels. M_3 (9% solution) level was found for the minimum accumulation of Cd in tuber peel and flesh, whereas ,M_0 (control) level was found for the maximum accumulation of Cd in tuber peel and flesh. Again Si_3 (300 $mgkg^{-1}$ soil) level was found for the minimum accumulation of Cd in tuber peel and flesh, whereas, Si_0 (control) level was found for the maximum accumulation of Cd in tuber peel and flesh. Among the treatment combinations, M_3Si_3 produced highest yield (493.05 g $plant^{-1}$) along with lower amount of Cd (0.0055$mgkg^{-1}$)dry wt. of tuber and 0.0025$mgkg^{-1}$dry wt. of peel) accumulation in compared to those of others. Therefore, farmer can produced potato in 10 mg kg^{-1} Cd contaminated soil treated with 9% solution of MSE with 300 $mgkg^{-1}$ soil Sodium Silicate.

CHAPTER 1

INTRODUCTION

Bangladesh is the world's eighth most populous country (2.2% of world's population; Wikipedia, 2016) burdened with many challenges including poverty, unemployment, corruption and Metal toxicity. Heavy metals are the metals with atomic masses over 20 and having a specific gravity of above 5g cm^{-3} or more. Nevertheless, some of these metals such as zinc, copper and nickel are essential micronutrients and are required in trace amounts as they act as cofactors for various enzymes. While other metals such as cadmium and lead present in pesticides do not have any beneficial role and become toxic if their concentration exceeds a certain limit. However, heavy metals (HMs) and metalloids are non-biodegradable in nature and can affect human health directly and indirectly. Natural and anthropogenic activities are the main causes of Cd contamination in different spheres of the environment. Heavy metals are released into the environment by both natural and anthropogenic sources. Some soils may have higher levels of heavy metals due to volcanic activity or weathering of parent materials. Due to various types of human activities such as tannery industries, pharmaceutical industries, low grade fertilizer (phosphate fertilizer) and pesticides application, automobiles, non-ferrous metal production as well as combustion of coal and oil and waste incineration etc., the soils of Bangladesh are contaminated with high concentrations of Cd. Moreover, Cd is produced mainly as a by-product from mining, smelting, and refining sulphide ores of zinc, and to a lesser degree, lead and copper.

Cadmium in the form of sulfate and chloride salts of cadmium is comparatively more water soluble, more mobile in soil and can bio accumulate (Moynihan *et al.,* 2017). Cadmium is highly toxic at very low exposure levels, and has acute and chronic effects on health and the environment (Islam, 2017).The WHO guideline value of 0.003 mg/l was set to protect against kidney damage and the Bangladesh standard in drinking water is 0.005 mg/l (UNICEF, 2011). According to the Bangladesh Standard Testing Institute standard, the maximum permissible level for Cd is 1mg kg^{-1} (BSTI, 2001).

Metal toxicity is one of the major threats to crop production because metals easily enter to the food chain and most are carcinogens (Hasanuzzaman *et al*., 2012).

Meanwhile, agricultural products from contaminated soil are frequently found to contain high concentrations of heavy metals and metalloids, which may impact human health profoundly. Different types of metal processing and textile industries have been established on the banks of rivers in Bangladesh. Cadmium from industrial dumping and emissions, along with sewage sludge, fertilizers and pesticides contaminate the soil, surface and ground water, and eventually leads to uptake by plants through the irrigation process and surface runoff.

Irrigation with contaminated ground water is also responsible for soil contamination. Agricultural soil irrigated with Shitalakhya river water in Narayanganj presents elevated Pb (28.13mg kg^{-1}), Cd (0.97mg kg^{-1}), and Cr (69.75mg kg^{-1}), which are higher than safe limits (Ratul *et al*., 2018).

Potato (*Solanum tuberosum* L.) is world's fourth most important food crop after Wheat, Maize and Rice extensively grown in 150 countries. Bangladesh is the 7^{th} potato producing country in the world with total area, production and yield is 0.4774 million hectares, 0.9744 crore MT and 20.41 t ha^{-1}, respectively (FAOSTAT, 2018). It ranks second after rice in production so it is one of the most valued crops in Bangladesh. As potato tuber is an underground modified stem, it has direct contact with soil. If soil and/or irrigation water be contaminated, it can be affected readily. Therefore, the tracking and minimizing of heavy metal concentrations to permissible level within potato tubers is important.

Si plays a significant role in alleviating the toxic effects of metals in plants by several mechanisms such as modifying metal uptake and translocation, metal binding to cell walls, and also co-precipitation with Si (Nascimento and Xing, 2006). It has been hypothesized that silicates have a high ability to convert soluble and exchangeable metals in the soil into non-soluble chemical complexes by a number of reactions (Liang *et al*., 2005). In plants, Si may alter translocation and distribution of metals in different parts of the plant that can help the plant to survive under higher metal stress (Zhang *et al.,* 2008). Hence, it should be used to increase plant growth and reduce heavy metal toxicity.

MSE is rich in some osmo-protectant and antioxidants. It is also rich in vitamins A and C, cytokinin, several minerals phenols, zeatin, and riboflavin. These compounds are natural stimulant for plant growth (Rady *et al*., 2013; Namblar *et al*., 2005). MSE proteins help in removing heavy metals ions from the soil at pH levels (6–8) (Sajidu *et al.,* 2006).The present study hypothesized that using both silicon and MSE can reduce the contamination of potato tubers with Cd.

The environmental fate and the toxicity of cadmium calls for a global initiative aimed at minimizing human and environmental consequences of the ongoing cadmium emissions. The relevance of considering a global initiative comes, furthermore, from the fact that cadmium used intentionally in products is traded globally and that effective risk reduction measures thus must be seen in a global context. Cadmium balances for farmland in Denmark, the Netherlands and Sweden shows accumulation of cadmium in top soil. Yearly accumulation rate has been calculated as 0.3% for Denmark and 0.6-0.7% for the Netherlands. In all cases the dominant sources are atmospheric deposition and commercial phosphate fertilizers (OECD, 1994).Cadmium is accumulating in top agricultural soils due to cadmium in phosphate fertilizers in several European countries (Hutton and Meeus, 2001).In world context, Cadmium levels of up to 5mg kg^{-1} have been reported in sediments from river and lakes, and from 0.03 - 1mg kg^{-1} in marine sediments has been reported in French and Norwegian coastal zones (OSPAR, 2002).

A number of international agreements have been established already in order to manage and control releases of cadmium to the environment and limit human and environmental exposure to cadmium such as OSPAR Convention, Helsinki Convention, Basel Convention etc.

Cadmium has been identified as a priority hazardous substance under the EC Water Framework directive and EC-regulation setting maximum levels of cadmium in food stuffs has been established.

The present research work was undertaken aiming to mitigate the Cd toxicity with following objectives-

1. To find out the toxic effect of Cd on potato
2. To determine the concentration of Cd in potato tuber
3. To study the effect of MSE and Si on yield and quality of potato

CHAPTER 2

REVIEW OF LITERATURE

2.1 Present Condition

Heavy metal and metalloid contamination from both geological and industrial sources has become a major issue for the people of Bangladesh in recent years. These risks mainly associated with mining, industrialization and urbanization. Rapid industrialization, urbanization and various anthropological activities also have driven the wide dispersion of cadmium (Cd), lead (Pb), and chromium (Cr) in the environment. Soil near the industrial areas of the big cities in Bangladesh, such as Dhaka, Gazipur, Chittagong, and Bogra, displayed excess heavy metals and metalloids (Rahman, 2012).

Hossain *et al.* (2019) studied about the Cd concentrations in rivers across Bangladesh. They observed that the highest concentration of Cd was in the Turag River (17 mg kg^{-1}), followed by the Buriganga River (3.3 mg kg^{-1}), the Karnaphuli River (2.01 mg kg^{-1}), the Korotoa River (1.5 mg kg^{-1}) and the Bangshi River (0.61 mg kg^{-1}).They found that Cd concentrations were comparatively higher in river sediments than in dietary products. In addition, Cd concentrations in the water of these rivers were low in comparison to those of sediment, indicating that Cd accumulates in river sediment by deposition processes.

Previous studies found that Cd concentrations in food were within permissible limit (BSTI, 2001 and WHO, 2011). But now it is clear that the population of Bangladesh has been more exposed to Cd pollution along with other heavy metals. However, Bangladeshis are unaware of Cd pollution or its adverse health impacts.

In the recent years, the use of shallow and deep tube-well water for irrigation and the use of excess amount of cheap fertilizers and pesticides containing cadmium pose a serious threat of contamination of arsenic and cadmium in food. In an exploratory study arsenic and cadmium were measured in foods from Matlab, a rural area in Bangladesh, that is extensively affected by arsenic and the economy is agriculture-based. Raw and cooked food samples were collected from village homes (households, n=13) and analyzed to quantify concentrations of arsenic and cadmium using atomic absorption spectrophotometry. The practice of discarding excess water while cooking rice reduces the concentration of arsenic but not of cadmium in cooked rice. The results suggest that arsenic and cadmium have entered the food-chain of Bangladesh, and the cooking practices influence the concentration of arsenic but not of cadmium in cooked food, (Khan *et al.,* 2010).

2.2 Cadmium effect

Studies reported a marked reduction in photosynthetic rate for different plant species under exposure to Cd stress (Sawhney *et al.,*1990; Sheoran *et al*., 1990a; 1990b).

The presence of excessive amount of Cd in soil causes many toxic symptoms in plants including reduction of growth, specially root growth (Weigel and Jager, 1980), disturbances in mineral nutrition and carbohydrate metabolism (Moya *et al*., 1993), and may therefore strongly reduce biomass production. The reduction of biomass by Cd toxicity might be the direct consequence of the inhibition of chlorophyll synthesis (Padmaja *et al.*, 1990) and photosynthesis (Bazzaz *et al.,*1975 and Baszynski *et al*., 1980).

Shi *et al.* (2010) performed an experiment to study the effects of Si on tissue and subcellular distribution of Cd in two contrasting peanut (*Arachis hypogaea* L.) cultivars differing in their Cd tolerance. The results showed that Cd exposure alone depressed plant growth and caused oxidative stress for both cultivars, and this toxicity was more obvious in Cd-sensitive cultivar than in Cd-tolerant cultivar.

Vegetables growing in medium with high level of Cd showed deleterious effect in photosynthetic processes, such as chlorophyll content and photosynthesis (Baszynski *et al*., 1980; Padmaja *et al.,* 1990; Satyakala, 1997), the activities of related enzymes (Ouariti *et al*., 1997a; Ascencio and Cedeno-Maldonado, 1979; Weigel, 1985a and 1985b) and photochemical reaction (Li and Miles, 1975; Skorzynska and Baszynski, 1995).

Dixit *et al.,* (2001) carried out an experiment in pea plants (*Pisum sativum* L. cv. Azad) where they found that Cd induces a decrease in plant biomass. The maximum accumulation of Cd occurred in roots followed by stems and leaves. An enhanced level of lipid per-oxidation and an increased tissue concentration of hydrogen peroxide (H2O2) in both roots and leaves indicated that Cd caused oxidative stress in pea plants. Roots and leaves of pea plants responded differently to Cd with reference to the induction of enhanced activities of most of the enzymes monitored in the study.

2.3 Mollification of Cd toxicity by using Moringa

Many studies have shown that use of Moringa plant parts decreases the heavy metal content. This decrease may be characterized by the presence of different functional group *viz* carbohydrate, lignin., fatty acid and protein units which further contains amino acid and carboxylic groups present in Moringa (Pagnanelli *et al.,* 2003).

MSE also acts as absorbant of lignocellulose which contains some groups *viz*. lignin, cellulose and hemicellulose. These group have functional activity to ion exchange and complex formation (Pagnanelli *et al.,* 2003).

Ali (2020) carried out an experiment on Removal of Heavy Metals from Water and Wastewater Using *Moringa oleifera*. He introduced *Moringa oleifera* cake residue, *Moringa oleifera* press cake, and *Moringa oleifera* leaves as a proposed alternative to replace conventional methods for heavy metal ions' (Cd, Cu, Fe and Pb) removal. The results of using *Moringa oleifera* cake residue showed that cadmium (Cd) were successfully removed up to 98%. The heavy metals were also successfully reduced using *Moringa oleifera* press cake. The removal percentage of Cd reached 93.73%. *Moringa oleifera* leaves were used to remove Cd (II) from synthetic water; the optimization was performed and each parameter was affecting the Cd (II) removal with different percentages, but pH was insignificant.

Howladar (2014) carried out an experiment with the bean plant in the presence of NaCl and/or $CdCl_2$ beginning from the second week, sprayed twice with moringa leaf extract (MLE) at 21 and 28 days after sowing (DAS), and were sampled at 35 DAS for growth and chemical analyses and yielded at the end of experiment. Growth traits, level of photosynthetic pigments, green pod yield and pod protein were significantly reduced with exposing the plants to NaCl and/or $CdCl_2$. However, the follow up foliar application with MLE detoxified the stress generated by NaCl and/or $CdCl_2$ and significantly enhanced the aforementioned parameters. Either individual or combined used stresses increased the electrolyte leakage (EL), lipid peroxidation and plant Cd^{2+}

content, and decreased the membrane stability index (MSI) and relative water content (RWC). However, the foliar application of MLE in the absence of the stress improved the MSI and RWC and minimized plant Cd^{2+} content but could not affect EL and lipid peroxidation. Proline content and the activity of antioxidant enzymes showed a significant increase in response to MLE as well as to NaCl and/or $CdCl_2$ stress.

Different studies revealed that use of Moringa had a mitigating effect on the removal of Cd from ground water(Maina *ei al*., 2016; Abirami and rohini, 2017; James and Zikankuba, 2017).

Shan *et al., (*2017) carried out an experiment to observe the use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal. They found that use of Moringa seeds resulted in the removal of Cd up to 98%.

2.4 Mollification of Cd toxicity by using Silicon

Silica is the second common element of soil content which has positive effects on the resistance of plants against biotic and abiotic stresses. Recently, the mitigating role of Si in cadmium stress has received some attention. However, its mechanisms involved remain poorly understood. This element can increase the yield, decrease the evaporation and perspiration and moreover, causes increasing of production of antioxidant enzymes , and less sensitivity to some fungal diseases. (Roohizadeh *et al*., 2014**).** Silica plays important role in the tolerance against Cd toxicity (Shi *et al*., 2010; and Vaculik *et al*., 2009).

Roohizadeh *et al.* (2014) carried out an experiment to study the effects of Sodium silicate on the total protein content, and the activities of catalase, peroxidase and superoxide dismutase of *Vicia faba L*. They treated the seeds of plant by sodium silicate. There were three doses (0,as control; 1.5 and 3 mM of sodium silicate) with three replications. The result showed that 1.5 mM treatment significantly increased the total protein content in comparison to control samples. The activity of catalase in the 3 mM treatment of Sodium silicate was significantly increased. The activity of Per-oxidase in the 3 mM treatments of Sodium silicate was significantly increased. In 3mM treatments of Sodium silicate also increased the activity of Superoxide Dismutase. Based on the results, it can be concluded that Nano silica particles can increase the activity of some antioxidant enzymes in broad bean, which in turn, brings about less damages caused by reactive oxygen species(ROS), and protects the plant's physiological processes against stresses.

A seven-one days pot experiment was conducted by Rizwan *et al.* (2012) in a previously Cd contaminated agricultural soil to investigate the effect of silicon on reducing Cd toxicity in durum wheat. There were 4 treatments of amorphous silica (ASi) at 0,1,10 and 15 on ASi ha^{-1} level. The study showed that application of ASi increases biomass and Si concentrations in plants, reduced the Cd availability in soil and Cd translocation to shoots.

Gu *et al*. (2011) carried out a pot experiment to study the mechanisms of stabilization of cadmium, zinc, copper and lead in a multi-metal contaminated acidic soil by Silicon-rich amendments and the mitigation of metal accumulation in rice were also investigated in that study. The results indicated that the application of fly ash (20 and 40 g kg^{-1}) and steel slag (3 and 6 g kg^{-1}) as Silicon-rich amendments, increased soil pH from 4.0 to 5.0–6.4, decreased the phyto availability of heavy metals by at least 60%, and further suppressed metal uptake by rice. A field experiment also showed that the trace element concentrations in polished rice treated with amendments complied with the food safety standard.

Shi *et al.* (2010) performed an experiment to study the effects of Si on tissue and sub cellular distribution of Cd in two contrasting peanut (*Arachis hypogaea L.*) cultivars differing in their Cd tolerance. The results showed that Cd exposure alone depressed plant growth and caused oxidative stress for both cultivars, and this toxicity was more obvious in Cd-sensitive cultivar than in Cd-tolerant cultivar.

Ping *et al*. (2008) out a pot experiment to study the effects of several amendments on rice growth and uptake of copper and cadmium from a contaminated soil. They investigated the effects of seven amendments on the growth of rice and uptake of heavy metals from a paddy soil which was contaminated by Cu and Cd. The result showed that application of Calcium silicate increases the grain yield and effectively decreased the Cu and Cd concentrations in grain.

Zhang *et al.* (2008) carried out an experiment to observe long-term effects of exogenous silicon on cadmium translocation and toxicity in rice (*Oryza sativa L.*). They found that silicon application decreased Cd concentrations in shoot by 30–50% and Cd distribution ratio in shoot by 25.3–46%, compared to control. The experiment concluded that Si enhances plant growth and decreases Cd accumulation in shoots and thereby helps to lower the potential risks of food contamination.

Liang *et al.* (2005) performed a pot experiment to study the alleviative effects of exogenous silicon (Si) on cadmium (Cd) phyto-toxicity in maize grown in an acid soil which was contaminated with Cd. They used five treatments in their experiments such as-control (neither Cd nor Si added), Cd added at 20 or 40 mg kg^{-1} Cd without or with Si added at 400 mg kg^{-1} Si. They found that Cd treatment significantly decreased shoot and root dry weight, while addition of Si at both levels significantly enhanced biomass.

Chen *et al*. (2000) carried out a pot experiment on effect of chemical methods and phyto-remediation on soil contaminated with heavy metals. They investigate the effects of chemical amendments on the growth and uptake of cadmium (Cd) by wetland rice, Chinese cabbage and wheat grown in a red soil contaminated with Cd. They used three treatments viz. calcium carbonate (CC), steel sludge (SS) and furnace slag (FS) as chemical amendments. Among the three amendments, FS was the most effcient at suppresing Cd uptake by the plants, probably due to its higher content of available silicon (Si).

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted during the period from November 2018 to February 2019 to study the mollifying effect of Moringa Seed Extract (MSE) and Silicon (Si) of Cd toxicity on potato tuber. The materials and methods describe a short description of the experimental site, climate condition of the storage room, experimental materials, experimental treatments and design, methods of the study, data collection procedure and procedure of data analysis. The detailed materials and methods that were used to conduct the study is presented below under the following heading:

3.1 Site Description

3.1.1 Geographical location

The experimental area was situated at $23^0 77'$ N latitude and $90^0 33'$ E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.1.2 Agro-Ecological Region

The experimental site belongs to the Agro-ecological zone of "Modhupur Tract", AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as "islands" surrounded by floodplain (Anon., 1988). Appendix II represents the map of the experimental site.

3.1.3 Climate

Experimental site was located in the subtropical monsoon climatic zone, set aparted by winter during the months from November to February (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for potato growing in Bangladesh. Appendix III represents monthly record of air temperature, relative humidity, railfall and sunshine hour from November'18 to February'19.

3.1.4 Soil characteristics

The soil of the experimental location belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils (FAOSTAT, 1988). In texture, the top soil was Silty Clay, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental site having available irrigation and drainage facilities and situated above flood level. The soil was composed of 26% sand, 43% silt and 31% clay particles and having a texture of sandy loam with organic matter 1.15%. Appendix IV represents details morphological, physical and chemical properties of the soil of experimental field.

3.2 Details Of The Experimental Treatment And Design

3.2.1 Treatments

The experiment consisted of 2 factors:

Factor A: Concentration of MSE (Moringa Seed Extract):

1. M_0: Control (0% solution in 50 ml water kg^{-1} soil)
2. M_1: 3% solution in 50 ml water kg^{-1} soil
3. M_2: 6% solution in 50 ml water kg^{-1} soil
4. M_3: 9% solution in 50 ml water kg^{-1} soil

Factor B: Level of Si as Sodium silicate:

1. Si_0: Control(0 mg kg^{-1} soil)
2. Si_1: 100 mg kg^{-1} soil
3. Si_2: 200 mg kg^{-1} soil
4. Si_3: 300 mg kg^{-1} soil

There were 16 treatment combinations : viz., M_0Si_0, M_0Si_1, M_0Si_2, M_0Si_3, M_1Si_0, M_1Si_1, M_1Si_2, M_1Si_3, M_2Si_0, M_2Si_1, M_2Si_2, M_2Si_3, M_3Si_0, M_3Si_1, M_3Si_2 and M_3Si_3..

3.2.2 Experimental design

The experiment was laid out in a simple Randomized Complete Block Design (RCBD) with four (4) replications thus comprised 64 baskets. The layout of the experiment has been shown in Appendix I.

3.3 Crop / Planting material

The planting materials comprised the certified seed tubers of BARI alu-7 (Diamant) varieties of potato.

3.4 Crop management and methods of the study

3.4.1 Seed collection

Seed potato (certified seed) was collected from, BARI sub-station, Debigonj, Panchagar District, Bangladesh. Individual weight of seed potato was 60-70 g. The collected tubers were free of any visible defects, disease symptoms and insect infestations and transported to the Laboratory of the Department of Agronomy, SAU, Dhaka with careful handling to avoid disease and injury.

3.4.2 Seed preparation

Collected seed tubers were kept in room temperature to facilitate sprouting. Finally full sprouted potato tubers were used as a planting material.

3.4.3 Soil and Baskets preparation

Soil was collected from farm of Sher-e-Bangla Agricultural University. The collected soil was sandy loam. Weeds and stubbles were completely removed from soil. Each basket was filled by 10 kg soil and which was mixed with well dried cow dung and packed in a poly pack. Poly pack was used to control leaching loss of arsenic by irrigation water. Baskets were filled up on 5th November, 2018 (7 days before planting).

3.4.4 Fertilizer application

The experimental soil of basket was fertilized with following dose of urea, triple super phosphate (TSP), Muriate of Potash (MP), gypsum, zinc sulfate and boric acid.

Table 1 Doses of manure and fertilizers in the potato field

Fertilizers	**Dose (kg ha^{-1})**	**Dose (g 10 kg soil^{-1})**
Cow dung	As per requirement	
Urea	350	1.75
TSP	220	1.10
MP	260	1.30
Gypsum	120	0.60
Zinc Sulphate	12	0.06
Boric Acid	6	0.03
$MnSO_4$	5	0.025

Source: Fertilizer Recommendation Guide, 2018(BARC)

The entire amounts of triple super phosphate, muriate of potash, gypsum, zinc sulphate, boric acid and one third of urea were applied as basal dose at 7 days before potato sowing. Rest urea was applied in two equal installments i.e., first was done at 30 DAP followed by first pouring the soil in pot for complete the earthing up in the field and second was at 50 DAP followed by pouring the soil in pot.

3.4.5 Soil Cadmium application

For the Cd treatment of soil, Cadmium Chloride ($CdCl_2$) was used as the source of Cd. Cd application was done by adding 10 mg kg^{-1} soil Cadmium Chloride into soil of baskets during mixing of cow dung.

3.4.6 Planting of seed tuber

Seed tubers were certified seed and that is why seed treating was not required. The well sprouted healthy and uniform sized (60-70 g) potato tubers were planted and a whole potato was used for one basket. Seed potatoes were planted in such a way that potato does not go much under soil or does not remain in shallow. On an average, potatoes were sown at 4-5 cm depth in basket on 12^{th} November, 2018.

3.4.7 Moringa Seed Extract (MSE) preparation

Moringa oleifera seeds used in this study were collected. The seeds were de-shelled to remove the kernels. Seed kernels were further dried at ambient temperature for a period of 5 days. The white kernels were milled into a fine powder using mourter-pastel and sieved (using 200–250 µm). 3%, 6% and 9% MSE extract were prepared by dispersing necessary amount of powder into different test tube according to the treatments. The individual suspensions were stirred and then kept for settled down about 1 hr. The collected supernatant were filtered through Wattman pleated filter (Kardam *et al.,* 2010).

The extract was used immediately after preparation. The whole seed was stored at 0ºC in the refrigerator and only taken out when needed for extract preparation.

3.4.8 Sodium silicate treatment

For the Si treatment of soil, Sodium silicate (Na_2SiO_3) was used as the source of Si. Si application was done by adding 100 mg kg^{-1} soil, 200 mg kg^{-1} soil and 300 mg kg^{-1} soil sodium silicate into soil of baskets according to treatment. Sodium silicate was collected from Tikatuli, Sutrapur, Dhaka.

3.4.9 Soil MSE and Si (as sodium silicate) application

MSE extract was diluted with 500ml of irrigation water for each basket(10 kg soil). And similarly sodium silicate was diluted. Prepared MSE extract and Sodium silicate solution were applied in equal doses immediate after irrigations. Four equal doses were given according to the treatments throughout the life cycle viz. at i. immediate after planting, ii. 30 DAP, iii. 45 DAP, iv. 60 DAP. Special attention was given for complete coverage of the plant root during watering.

3.4.10 Intercultural operations

Whenever the seedling start to emerge the mulch materials(rice straw) were removed to facilitate emergence. Following intercultural operation were done to accomplish the growth and development of potato plant and tuber.

Weeding

Weeding was performed in all baskets as and when required to keep plant free from weeds. Manual hand weeding was done frequently as necessarily.

Watering

Frequency of watering depended upon soil moisture status by observing visually. Hence total 6 irrigations were given. However avoiding water logging, as it is detrimental to plants.

Earthing up

Earthing up process was done by pouring the soil in the pot at two times during crop growing period. First pouring was done after 45 days after planting and second was after 60 days of planting.

Disease and pest management

No insects were found harmful for potato in growing season as the whole experimental site was protected by net covering (Plate attached). To protect the soil borne insects Furadan 5G was applied @10 kg ha^{-1} during the final land preparation. Dithane M-45 was applied @ 2g L^{-1} at 10 days interval as a preventive measure against late blight *(Phytophthora infestans)* of potato. Only two of the plants was affected by bacterial wilt which did not hampered on plant growth.

Haulm cutting

Haulm cutting was done at 13th February at 90 days after planting, when 40- 50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection.

Harvesting of potatoes

Harvesting of potato was done at 20th February at 7 days after haulm cutting. The potatoes of each basket were separately harvested, bagged and tagged and brought to the laboratory. The potato yield basket^{-1} was determined in gram. The basket was set at 60 cm × 25 cm spacing, considering 66666 baskets were accommodated in 1 ha area.

3.4.11 Recording of data

Experimental data were determined from 30 days of growth duration and continued until harvest. One plant was randomly selected and marked with polythene rope from each pot for collecting data on growth, yield and quality parameters. The crop was harvested pot-wise at full maturity on the 20th February, 2019. For collecting necessary data, the sample plants were harvested separately. The followings data were determined during the experiment. The harvested crop of each pot was bundled separately, tagged properly and taken to the lab. Some samples were dried in the sun for recording the dry weight. They were dried up to a constant moisture content level. Potato yields were recorded as gm plant^{-1}.

A. Crop growth characters

i. Days to emergence (Visual observation)

ii. Plant height (cm) (at 30, 45, 60 and 75 DAP)

iii. Number of leaves plant^{-1}(at 30, 45, 60 and 75 DAP)

iv. Number of stems hill^{-1}(at 30, 45, 60 and 75 DAP)

v. SPAD value of leaf (%) (at 30 DAP)

vi. Stem diameter (cm) (at 30, 45, 60 and 75 DAP)

vii. Days to maturity (Visual observation)

B. Yield and yield components

i. Number of tubers plant^{-1}

ii. Average weight of individual tuber (g)

iii. Weight of tubers plant^{-1} (g)

iv. Marketable and non-marketable yield (% by number and % by weight)

C. Quality characters

i. Stem dry matter content(%)

ii. Tuber flesh dry matter content(%)

iii. Tuber peel dry matter content(%)

iv. Total soluble solids content of tuber(%)

v. Specific gravity of tuber (g cm^{-3})

vi. Cadmium content of tuber peel (mgkg^{-1} dw)

vii. Cadmium content of tuber flesh (mgkg^{-1} dw)

3.4.12 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study is given below:

A. Crop growth characters

i. Days to emergence

Days to emergence was counted the days required for emergence from the date of potato tuber sowing.

ii. Days to maturity

Days to maturity data was recorded by visual observation. When sixty percent leaf are yellow of a plant considered as a hundred percent mature.

iii. Plant height(cm)

Plant height was measured at 30, 45, 60 and 75 DAP. The height of each plant of each basket was measured in cm by using meter scale and mean was calculated.

iv. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at 30, 45, 60 and 75 DAP. Leaves number plant^{-1} were recorded by counting all leaves from each plant of each basket and mean was calculated.

v. Number of stems plant^{-1}

Number of stems hill^{-1} was counted at 30, 45, 60 and 75 DAP. Stem numbers hill^{-1}was recorded by counting all stem from each basket.

vi. Stem diameter(cm)

Stem diameter was measured at 30, 45, 60 and 75 DAP. The stem diameter of each plant of each basket was measured in cm by using Slide Calipers and mean was calculated.

vii. SPAD value of leaf(%)

The SPAD value of leaves was measured at stolon initiation stage at 30 DAP by placing the Spadometer in middle point of any five leaves of previously tagged plant from each pot and then the percentage showed by the Spadometer was observed and recorded.

B. Yield and yield components

i. Number of tubers plant^{-1}

Number of tubers plant^{-1} was counted at harvest. Tuber numbers plant^{-1} was recorded by counting all tubers from each basket.

ii. Average weight of individual tuber (g)

Average weight of individual tubers were estimated by dividing the weight of tubers plant^{-1} with the number of tubers plant^{-1}.

iii. Weight of tubers plant^{-1} (g)

Tubers of each plant were collected separately from which weight of tuber plant^{-1} was recorded in gram.

iv. Grading of tuber

Harvested tubers were graded into on the basis of % by number and by weight. Tubers have been graded into marketable tuber (> 20 g) and non-marketable tuber (< 20 g).

C. Quality Characters

i. Stem dry matter content(%)

Fresh weight of haulm was taken first then dried under sunshine for a 3 days and then dried in an oven at 70°C for 72 hours(dried until a constant moisture level). The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. Then the dry matter percentage of above ground harvest was calculated with the following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{fresh weight}} \times 100$$

ii. Tuber flesh dry matter content(%)

The samples of tuber were collected from each treatment. After peeling off and chopping, was dried under sunshine for a 3 days. Then the tubers the samples were dried in oven at 72^0 C for 72 hours(until a constant moisture level) and transferred into desiccators and allowed to cool down at room temperature. Then the dry matter percentage was recorded. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage.

Dry matter content (%) = $\frac{\text{Dry weight}}{\text{fresh weight}} \times 100$

iii. Tuber peel dry matter content(%)

The peel of tubers of each sample was collected from each treatment and was dried under sunshine for a 3 days. Then the tubers the samples were dried in oven at 72^0 C for 72 hours(until a constant moisture level) and transferred into desiccators and allowed to cool down at room temperature. Then the dry matter percentage was recorded. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage.

iv. Total soluble solids content of tuber

TSS of harvested tubers was determined in a drop of potato juice by using Hand Sugar Refractometer “ERMA” Japan, Range: 0-32% according to (AOAC, 1990) and recorded as % Brix from direct reading of the instrument. Three tuber samples were taken from each treatment to determine total soluble solids then calculate average value from three sample data.

v. Specific gravity of tuber

Specific gravity of potato tubers was measured by using the following formula (Gould, 1995). Five tubers were taken from each plot after harvest of treatment and then the means were taken.

$$\text{Specific gravity} = \frac{Wa}{Ww} \times 100\ \%$$

Where,

W_a = Weight of tuber (g) in air and

W_w = Weight of tubers (g) in fresh water at 4^0C

3.4.13 Preparation for chemical analysis

Potatoes were harvested and packed with labeled polythene bag. These labeled packed tubers were immediately sent to the laboratory of Soil and Environmental Research Section, Biological Research Division, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. After peel out the tuber; tuber sample and tuber peel sample separated in different labeled packed. Then the samples were sent to Analytical Laboratory where As was determined with Atomic Absorption Spectrophotometer.

3.4.14 Procedure of chemical analysis

3.4.14.1 Sun drying and Oven drying

Firstly, potato tubers were peeled off. Then the tubers and peels were sun dried separately according to treatment. After that all were packed properly and taken for oven drying. They were oven-dried at 70^0C for 72 hours so that can obtain a constant moisture content.

3.4.14.2 Granding

The oven dried samples were then ground by a grinder and about 0.5g samples were taken for the digestion process. 5ml 70% HNO_3 and 5ml H_2O_2chemicals were used for the digestion process.

3.4.14.3 Nitric acid digestion

This approach was partly modified from that of Zheljazkov and Nielson (1996). 0.5g sample was taken in a 25ml beaker for each. 5ml 70% HNO_3 was added for pre-digestion process, cover them and it was predigested for about 24 hour. After that, again 5ml HNO_3 was added to the samples and heated them for 30 minute with 80°C. Then finally temperature was raised up to 150°C at which samples were started to boil for at least 2 hour until clear solution was obtained. Those samples were cooled at room temperature and the interior walls of the beakers were washed down with a little distilled water and the beaker was swirled throughout the digestion to keep the wall clean and prevent the loss of the samples. Then 5ml 30% $H_2O_2$was added and heat them at 220°C for 1 hour until the volume was reduced to 1ml. After cooling the samples, those were volume in a 25ml volumetric flask with distilled water. Each samples were then filtrate with Whatman No. 42 filter paper.

3.4.14.4 Estimation of Cadmium (Cd) content on potato tubers and peel:

Final solutions were taken to estimate the concentration of Cadmium (Cd) by an Atomic Absorption Spectrometer (AAS).

3.4.15 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance (ANOVA) techniques by using Statistix 10 (2013) computer package program to find out the significant variances of the recorded parameters for different treatments. The significant differences among the treatment means were compared by Least Significant Differences (LSD) at 5% level of probability (Gomez and Gomez, 1984) .

CHAPTER 4

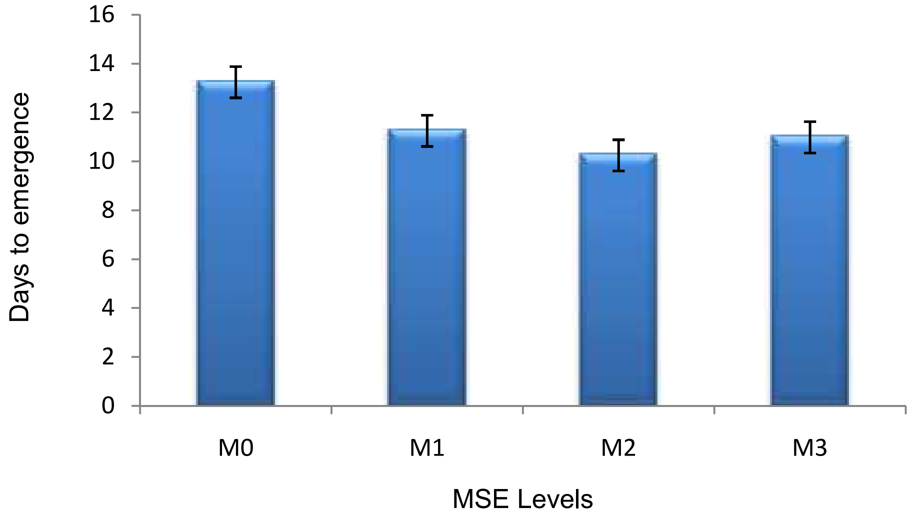
RESULT AND DISCUSSION

The research work was accomplished to investigate the effect of Cd on growth, yield and quality of potato and to observe the mollifying effect of MSE and Si on Cd toxicity. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The analysis of variance of data respect of all the parameters has been shown in Appendix IV-XII. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under following headings.

4.1 Days to emergence (Visual observation)

Days to emergence was significantly affected by MSE levels (Appendix IV) . Figure 1 showed that days to emergence increased with increasing MSE levels. The minimum duration (10.25 days) required in M_2 treatment where M_3 and M_1 required 10.985 days and 11.250 days respectively. Most delay occurred in M_0 (13.238 days) treatment. Similar trend of results on day to emergence and germination were also achieved by Phiri (2010). *M. oleifera* leaf extracts enhanced ($p \leq 0.05$) germination of rice by 25% and reduced ($p > 0.001$) germination percentage of rice by 7%. *M. oleifera* leaf extracts increased ($p > 0.001$) growth of hypocotyls by 42.9% in sorghum. *M. oleifera* increased ($p > 0.001$) radicle length of maize by 77.8%.

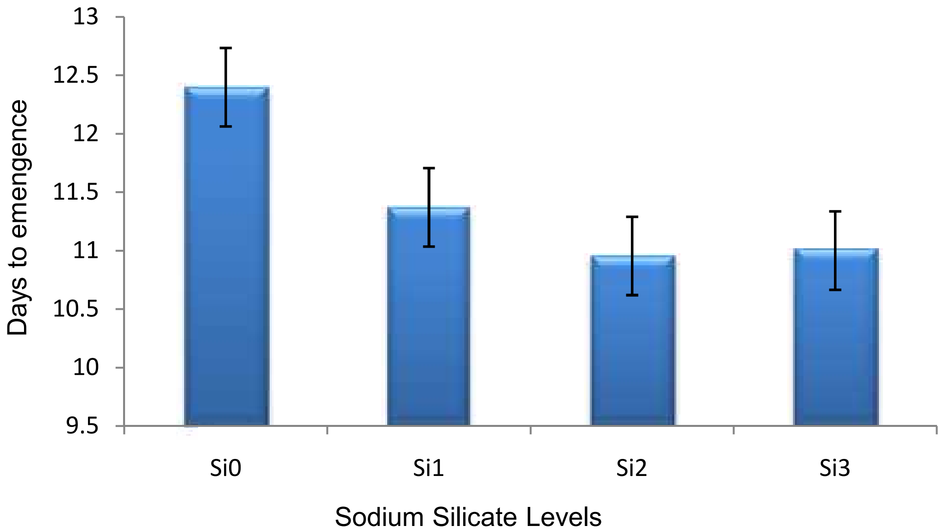
Days to emergence was also significantly ($P \leq 0.01$) affected by Si levels (Appendix IV). Days to emergence decreased with increasing Si levels. The minimum period (9.55 days) required in Si_2 treatment which was statistically similar to Si_3 (11.00 days). Si_1 treatment required 11.37 days and delayed in Si_0 (12.398 days).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 1. Effect of Moringa Seed Extract levels on days to emergence [LSD value: 0.1152]

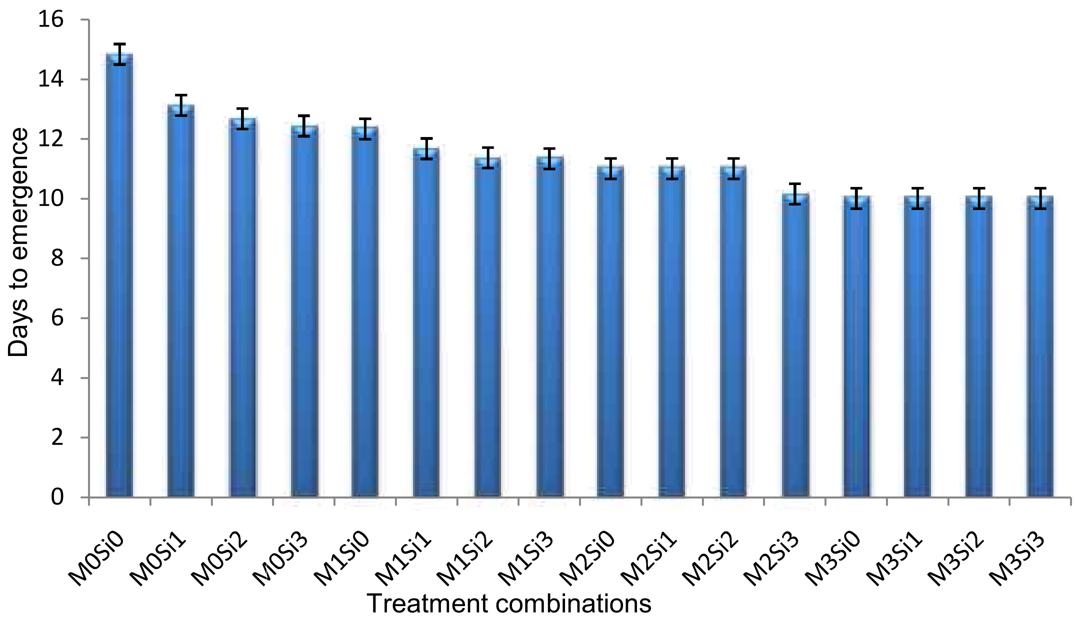


Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;
Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 2. Effect of Sodium Silicate levels on days to emergence of potato [LSD value: 0.1152]

Combined effects of sawdust and As levels significantly ($P \leq 0.01$) influenced by days taken to emergence of potato tubers (Appendix IV). The treatment combination M_3Si_3 required minimum days (10) for emergence which was statistically similar to M_3Si_2 (10 days), M_3Si_1 (10 days), M_3Si_0 (10 days), M_2Si_3 (10.15 days). Whereas the maximum days required for M_0Si_0(14.83 days) (Figure 3).



MSE-Moringa Seed extract levels	Si- Sodium Silicate levels
M_0: Control(0% MSE solution)	Si_0:Control(0 mg kg^{-1} soil)
M_1: 3% MSE solution;	Si_1: 100 mg kg^{-1} soil;
M_2: 6% MSE solution	Si_2;200 mg kg^{-1} soil;
M_3: 9% MSE solution	Si_3:300 mg kg^{-1} soil

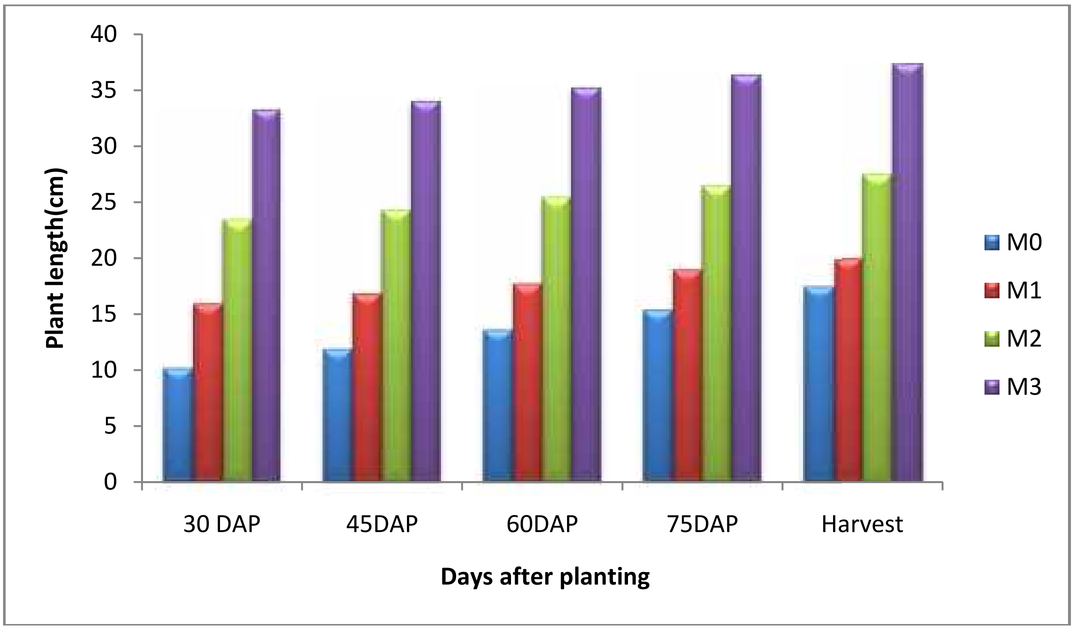
Figure 3. Combined effects of MSE and different Si levels on days to emergence of potato [LSD value: 0.2303]

4.2 Plant Length(cm)

Plant length was significantly ($P \leq 0.01$) affected by different MSE levels at 30, 45, 60 and 75 DAP (Appendix VI). Table 2 shows that plant height gradually increased with increasing MSE levels. The tallest plant was recorded in control M_3 (37.181 cm) at harvesting stage while the shortest plant was scored in M_0 (10.67 cm) at 30 DAP (Figure 4).

Plant length varies statistically significantly ($P \leq 0.01$) among different Si levels at 30, 45, 60, and 75 DAP (Appendix V). Table 2 shows that numerically the tallest plant in Si_3 (27.756 cm) was recorded while the shortest plant was in Si_0 (17.544

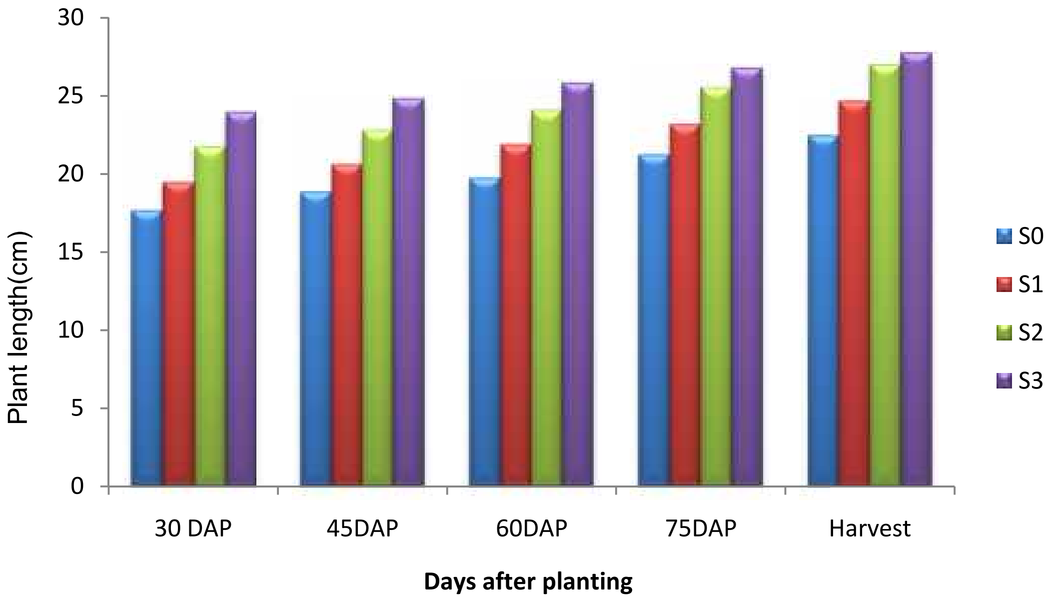
cm)(Figure 5).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 4. Effect of Moringa Seed Extract levels on Plant length [LSD value 0.1162, 0.2223, 0.2788, 0.2924 and 0.4348 at 30, 45, 60, 75 DAP and at harvest respectively]



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;
Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 5. Effect of Sodium Silicate levels on Plant length (cm) [LSD value 0.1162,

0.2223, 0.2788, 0.2924 and 0.4348 at 30, 45, 60, 75 DAP and at harvest respectively]

Table 2. Effect of MSE and Si levels on Plant length (cm) at different days of planting

Treatments	Plant length (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Levels of MSE					
M_0	10.094d	11.856d	13.519d	15.312d	17.450d
M_1	15.850c	16.838c	17.613c	18.869c	19.894c
M_2	23.288b	24.313b	25.281b	26.331b	27.338b
M_3	33.069a	34.000a	35.019a	36.213a	37.181a
$LSD_{(0.05)}$	0.1162	0.2223	0.2788	0.2924	0.4348
Level of significance	**	**	**	**	**
CV(%)	1.25	1.49	1.68	1.66	2.34
Levels of Si					
Si_0	17.544d	18.850d	19.725d	21.219d	22.438d
Si_1	19.350c	20.600c	21.850c	23.175c	24.662c
Si_2	21.594b	22.762b	24.050b	25.531b	27.006b
Si_3	23.812a	24.794a	25.806a	26.800a	27.756a
$LSD_{(0.05)}$	0.1162	0.2223	0.2788	0.2924	0.4348
Level of significance	**	**	**	**	**
CV(%)	1.25	1.49	1.68	1.66	2.34

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Combined effect of different MSE and Si levels on potato in terms of plant height also showed significant ($P \leq 0.05$) variation (Appendix V). Plant height of potato varieties observed statistically significant among treatments at 30, 45, 60,75 DAP and at harvest. The tallest plant was observed under M_3Si_3 (42.075 cm) at harvest while the shortest plant was found in M_0Si_0 (8.300 cm) at 30 DAP.

Table 3. Combined Effect of MSE and Si levels on Plant length (cm) at different days of planting

Treatments	Plant length (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
M_0Si_0	8.300p	10.375p	12.025n	13.850n	15.625n
M_0Si_1	9.350o	11.425o	13.225m	15.450 m	16.375n
M_0Si_2	10.425n	12.300n	14.350l	15.550m	17.475m
M_0Si_3	12.300m	13.325m	14.350l	16.350l	18.425l
M_1Si_0	13.375l	14.350l	14.475l	16.400l	19.375k
M_1Si_1	15.425k	16.350k	17.425k	18.400k	19.425k
M_1Si_2	16.300j	17.325j	18.350j	19.375 j	20.325j
M_1Si_3	18.300i	19.325i	20.325i	21.350i	22.350i
M_2Si_0	20.200h	21.32h	22.300h	23.375h	24.400h
M_2Si_1	22.300g	23.200g	24.350g	25.325g	26.400g
M_2Si2	24.350f	25.425f	26.250f	27.350f	28.325f
M_2Si_3	26.300e	27.300e	28.225e	29.275e	30.225e
M_3Si_0	28.300d	29.350d	30.225d	31.300d	32.250d
M_3Si_1	30.325c	31.425c	32.400c	33.425c	34.400c
M_3Si_2	35.300b	36.000b	37.250b	39.000b	40.000b
M_3Si_3	38.350a	39.225a	40.200a	41.125a	42.075a
$LSD_{(0.05)}$	0.2323	0.4447	0.5576	0.5849	0.8696
Level of significance	**	**	**	**	**
CV(%)	1.25	1.49	1.68	1.66	2.34

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

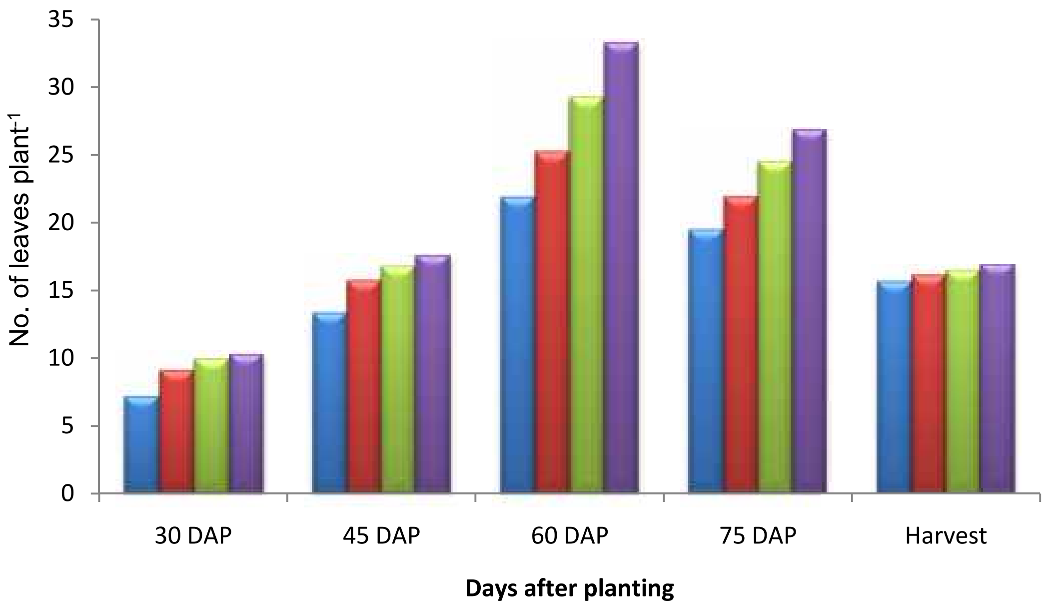
MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.3 Number of leaves plant^{-1}

No. of leaves number plant^{-1} of potato varied statistically significantly ($P \leq 0.05$) among different s MSE levels at 30, 45, 60 and 75 DAP (Appendix VII). Figure 6 shows that number of leaves plant^{-1} increased with increasing the MSE levels up to 60 DAP and thereafter decreased with advancing the growing period. Leaves number plant^{-1} was maximum at 60 DAP after then it decreased at 75 DAP due to early leaves senescence. The maximum number of leaves was recorded in M_3 (33.310) at 60 DAP whereas the minimum was recorded in M_0 (7.159) at 30 DAP (Table 4**).**

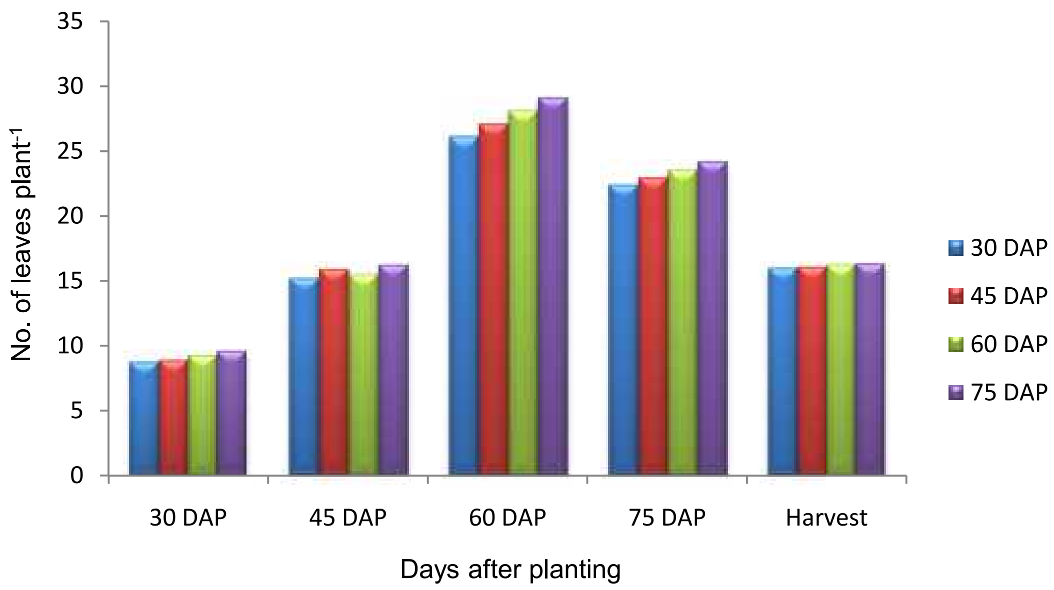
No. of leaves number plant^{-1} of potato was statistically also significant among different Si levels at 30, 45, 60 and 75 DAP (Appendix VII). Figure 7 showed that numerically maximum number of leaves plant^{-1} was recorded in Si_3 (28.943) at 60 DAP whereas the minimum was recorded in Si_0(8.737) at 30 DAP (Table 4).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 6. Effect of Moringa Seed Extract levels on No. of leaves plant^{-1} [LSD value 0.6294, 0.3327, 0.7243, 0.4485 and 0.5572 at 30, 45, 60, 75 DAP and at harvest respectively]



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 7. Effect of Sodium silicate levels on No. of leaves $plant^{-1}$ [LSD value 0.6294, 0.3327, 0.7243, 0.4485 and 0.5572 at 30, 45, 60, 75 DAP and at harvest respectively]

Combined effects of MSE and Si levels in terms of number of leaf $plant^{-1}$ was also exposed significant variation among treatment combinations at 30, 45, 60 and 75 DAP (Appendix VII). Table 5 showed that the maximum number of leaves $plant^{-1}$ was recorded from M_3Si_3 (34.990) at 60 DAP while the minimum was recorded from M_0Si_0(6.400) treatment combination at 30 DAP. Elrys *et al.,* (2018) also observed similar trends of increment of no. of leaves in potato plants for MSE treatment and potassium silicate in their studies.

Table 4. Effect of MSE and Si levels on No. of leaves plant^{-1} at different days of planting

Treatments	No. of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Levels of MSE					
M_0	7.159d	13.211d	21.942d	19.411d	15.516d
M_1	9.093c	15.596c	25.251c	21.837c	15.979c
M_2	9.948b	16.636b	29.260b	24.379b	16.346b
M_3	10.273a	17.439a	33.310a	26.739a	16.780a
$LSD_{(0.05)}$	0.1099	0.1303	0.1274	0.0956	0.1468
Level of significance	**	**	**	**	**
CV(%)	1.69	1.16	0.65	0.58	1.28
Levels of Si					
Si_0	8.7375d	15.210d	25.946d	22.218d	16.002c
Si_1	8.8838c	15.923b	26.914c	22.770c	16.101bc
Si_2	9.2581b	15.513c	27.961b	23.370b	16.218ab
Si_3	9.5931a	16.236a	28.943a	24.008a	16.301a
$LSD_{(0.05)}$	0.1099	0.1303	0.1274	0.0956	0.1468
Level of significance	*	*	**	*	*
CV(%)	1.69	1.16	0.65	0.58	1.28

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance *indicates 5% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 5. Combined Effect of MSE and Si levels on No. of leaves plant^{-1} at different days of planting

Treatments	No. of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
M_0Si_0	6.400i	12.360j	20.655p	18.710p	15.342i
M_0Si_1	6.630h	12.830i	21.393o	19.208o	15.500i
M_0Si_2	7.460g	13.570h	22.467n	19.620n	15.605hi
M_0Si_3	8.147f	14.085g	23.252m	20.105m	15.615hi
M_1Si_0	8.692e	14.535f	23.838l	20.838l	15.855gh
M_1Si_1	8.947d	14.535f	24.667k	21.557k	15.860gh
M_1Si_2	9.160d	15.050e	25.758j	22.167j	16.068fg
M_1Si_3	9.573c	15.050e	26.743i	22.785i	16.135efg
M_2Si_0	9.610c	15.868d	27.648h	23.473h	16.173ef
M_2Si_1	9.755c	15.868d	28.740g	24.065g	16.350def
M_2Si_2	10.150b	16.930c	29.868f	24.658f	16.392cde
M_2Si_3	10.275ab	16.930c	30.785e	25.322e	16.470cd
M_3Si_0	10.248ab	18.078b	31.645d	25.850d	16.638bcd
M_3Si_1	10.203ab	18.078b	32.855c	26.250c	16.650bc
M_3Si_2	10.263ab	18.880a	33.750b	27.035b	16.838ab
M_3Si_3	10.378a	18.880a	34.990a	27.820a	16.995a
$LSD_{(0.05)}$	0.2198	0.2606	0.2547	0.1911	0.2936
Level of significance	*	*	*	*	*
CV(%)	1.69	1.16	0.65	0.58	1.28

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

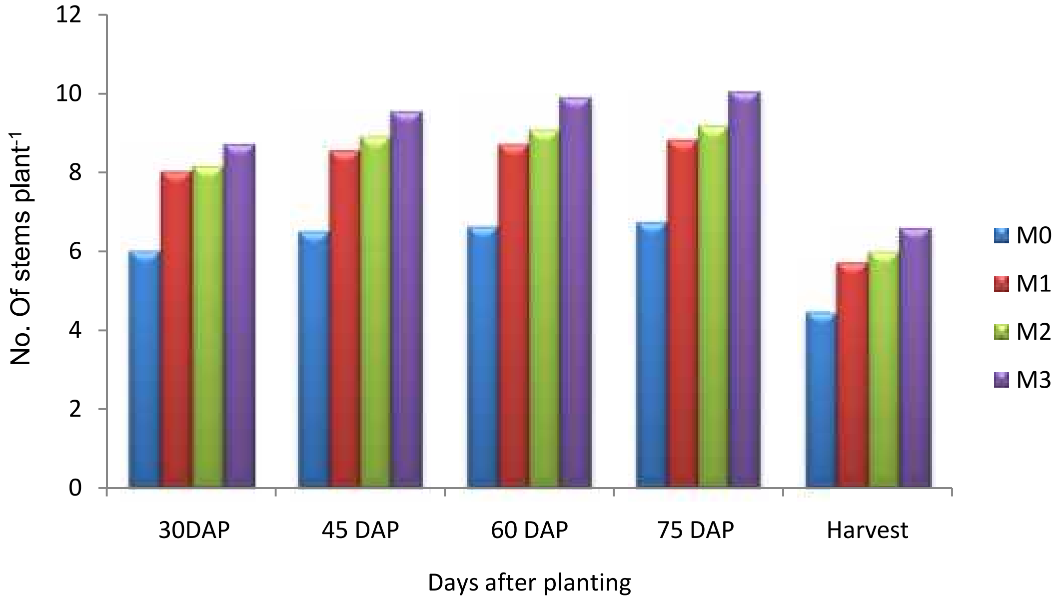
*indicates 5% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.4 Number of stems plant^{-1}

Stem numbers plant^{-1} of potato showed statistically significant($P \leq 0.01$) among different MSE levels at 30, 45, 60 and 75 DAP (Appendix VIII). Figure 8 showed that stem numbers plant^{-1} increased with increasing MSE levels. The maximum number of stems plant^{-1} was recorded in M_3 at 75 DAP (9.9875) while the minimum number of stems plant^{-1} was recorded in M_0 at 30 (5.9506) (Table 6).

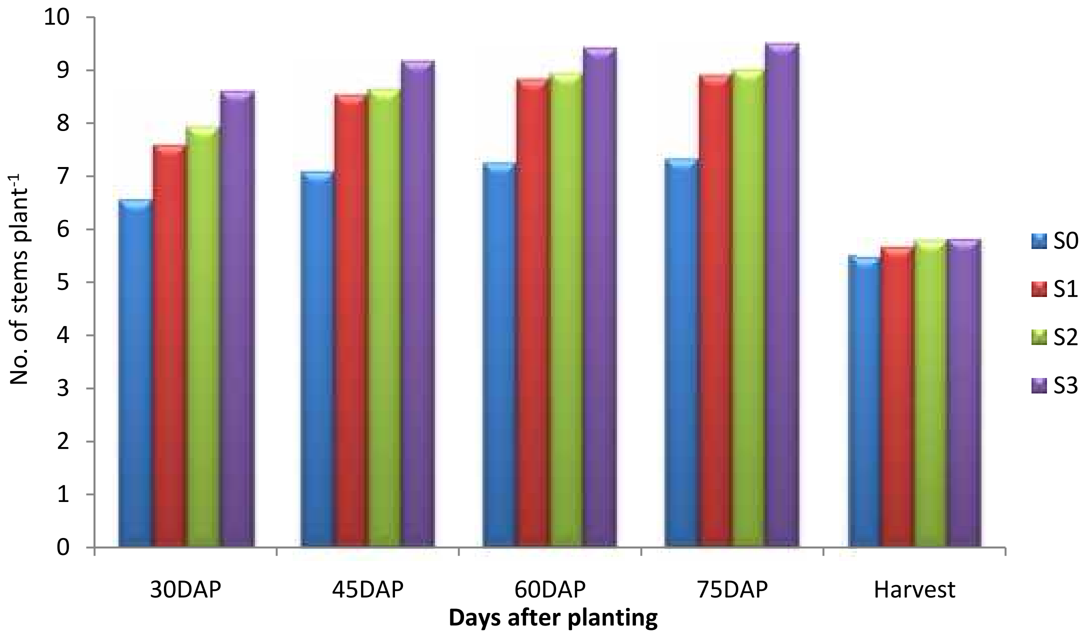


MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2**:** 6% MSE solution M_3:, 9% MSE solution

Figure 8. Effect of Moringa Seed Extract levels on Number of stems plant^{-1}[LSD value 0.4689, 0.3327, 0.7243, 0.4485 and 0.5572 at 30, 45, 60, 75 DAP and at harvest respectively]

Stem numbers plant^{-1} of potato exposed statistically non-significant among different Si at 30, 45, 60 and 75 DAP (Appendix VIII). Figure 9 shows numerically stem numbers plant^{-1} increased with the increasing levels of sodium silicate the maximum number of stems hill^{-1} was recorded at 75 DAP (9.4594) in Si_3 whereas the minimum was recorded at 30 (6.5538) DAP in Si_0.



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 9. Effect of Sodium silicate levels on No. of stems plant^{-1} [LSD value 0.6294, 0.3327, 0.7243, 0.4485 and 0.5572 at 30, 45, 60, 75 DAP and at harvest respectively.

Combined effects of MSE and Si levels on potato in terms of stem numbers plant^{-1} also exposed significant variation at 30, 45, 60 and 75 DAP (Appendix VIII). The maximum stem number plant^{-1} was recorded in M_3Si_3 (11.208) at 75 DAP, whereas the minimum was recorded from M_0Si_0 (3.9225) treatment combination at 30 DAP (table 7).

Table 6. Effect of MSE and Si levels on No. of stems plant^{-1} at different days of planting

Treatments	No. of stems plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Levels of MSE					
M_0	5.9506c	6.4569c	6.6163c	6.6950c	4.4231c
M_1	7.9675b	8.5081b	8.7094b	8.7769b	5.7137b
M_2	8.0975b	8.8450b	9.0744b	9.1231b	5.9869b
M_3	8.6594a	9.4863a	9.900a	9.9875a	6.5863a
$LSD_{(0.05)}$	0.4689	0.3920	0.3980	0.3952	0.3624
Level of significance	*	*	*	*	*
CV(%)	8.59	6.61	6.52	6.42	8.96
Levels of Si					
Si_0	6.5538c	7.0594c	7.2250c	7.2950c	5.4650a
Si_1	7.5856b	8.4981b	8.7931b	8.8638 b	5.6613a
Si_2	7.9300b	8.6050b	8.9006b	8.9644 b	5.7819a
Si_3	8.6056a	9.1338a	9.3819a	9.4594a	5.8019a
$LSD_{(0.05)}$	0.4689	0.3920	0.3980	0.3952	0.3624
Level of significance	NS	NS	NS	NS	NS
CV(%)	8.59	6.61	6.52	6.42	8.96

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

*indicates 5% level of significance NS indicates Non-significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 7. Combined Effect of MSE and Si levels on No. of stems plant^{-1} at different days of planting

Treatments	No. of stems plant^{-1}				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
M_0Si_0	3.9225h	4.223i	4.293j	4.390j	4.1850f
M_0Si_1	5.5650g	6.625h	6.855i	6.935i	4.3750f
M_0Si_2	6.6450f	7.270gh	7.452hi	7.552hi	4.5150f
M_0Si_3	7.0000ef	7.668fg	7.865gh	7.902gh	4.6175f
M_1Si_0	7.3925def	7.710fg	7.868gh	7.913gh	5.3675e
M_1Si_1	7.6225cde	7.963fg	8.080gh	8.135fgh	5.7925de
M_1Si_2	7.6700cde	8.385def	8.660efg	8.743def	5.8700cde
M_1Si_3	7.6700cde	8.105ef	8.302fg	8.383efg	5.8250cde
M_2Si_0	8.0875bcd	8.838cde	9.062def	9.095de	5.8325cde
M_2Si_1	8.3500bc	8.965cd	9.215cde	9.288cd	5.9550b-e
M_2Si_2	8.3550bc	9.000bcd	9.240b-e	9.303bcd	6.1325a-d
M_2Si_3	8.4375bc	9.108bcd	9.380b-e	9.440bcd	6.0275a-e
M_3Si_0	8.4575bc	9.313bc	9.847bcd	9.907bc	6.4750a-d
M_3Si_1	8.6375b	9.495bc	9.988bc	10.045bc	6.5225abc
M_3Si_2	8.9475b	9.767b	10.028b	10.093b	6.6100ab
M_3Si_3	9.9400a	10.753a	11.067a	11.208a	6.7375a
$LSD_{(0.05)}$	0.9378	0.7841	0.7960	0.7904	0.7248
Level of significance	**	**	**	**	**
CV(%)	8.59	6.61	6.52	6.42	8.96

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

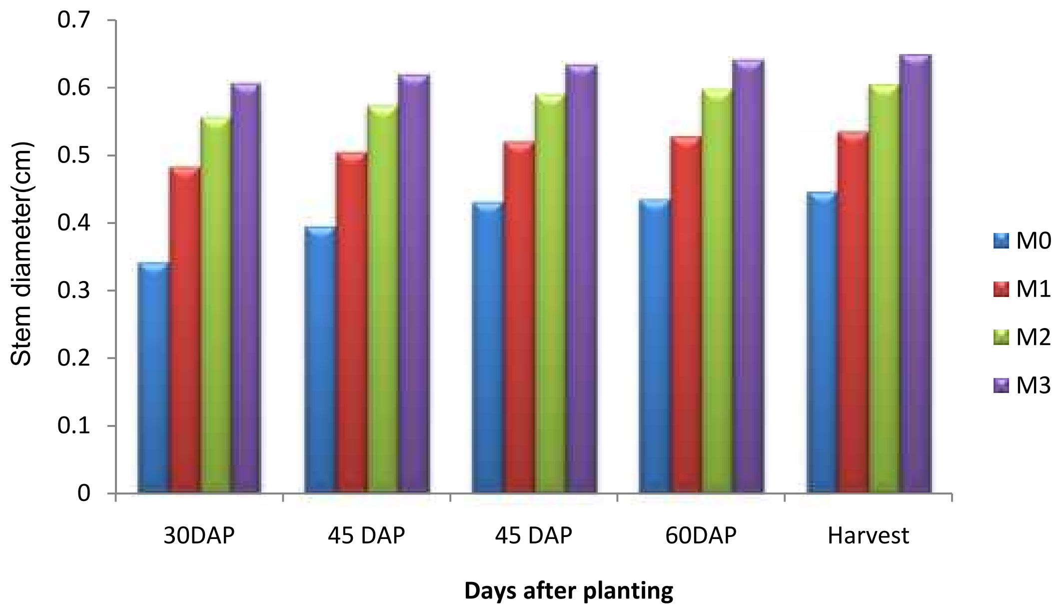
MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.5 Stem diameter(cm)

Stem diameter of potato showed significant(($P \leq 0.01$)result among MSE levels at 30, 45, 60 and 75 DAP (Appendix IX). Figure 10 showed that effect of MSE levels on stem diameter has a positive influence which indicated that the stem diameter increased gradually with increasing MSE levels. The widest stem diameter was recorded at 75 DAP in M_3 (0.679 cm) and the narrowest was recorded at 30 DAP in M_0 (0.248 cm).

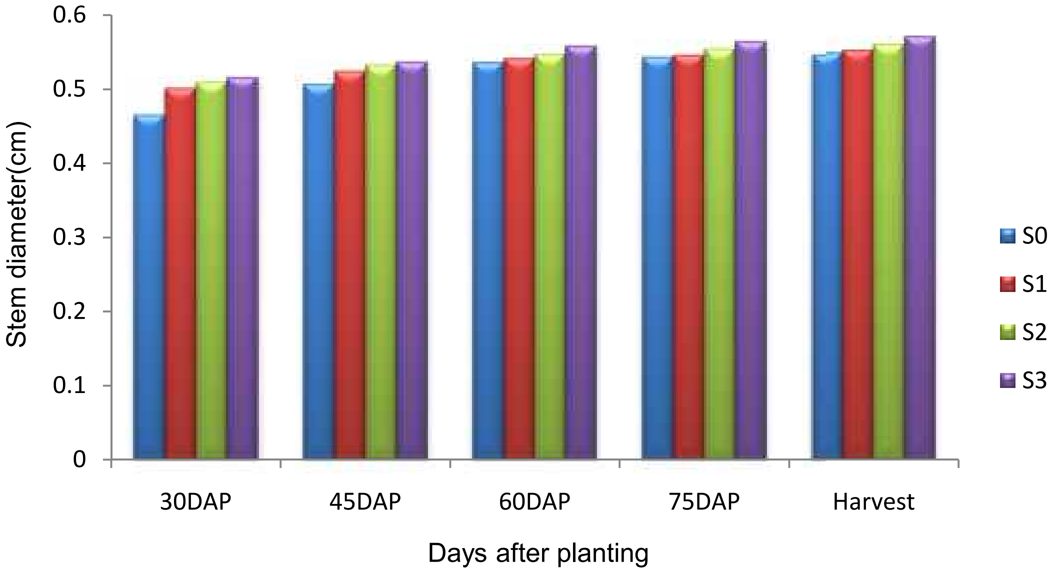
Stem diameter of potato was non-significant by different Si levels at 30, 45, 60 and 75 DAP (Appendix IX). Figure 11 showed that stem diameter increased with increasing the Si levels in soil. The widest stem diameter was recorded at 75 DAP in Si_3 (0.5684 cm) and the narrowest stem diameter was recorded at 30 DAP in Si_0 (0.4627 cm) (Table 8).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 10. Effect of Moringa Seed Extract levels on Stem diameter (cm) [LSD value 0.0395, 0.0370, 0.0356, 0.0351 and 0.0347 at 30, 45, 60, 75 DAP and at harvest respectively]



Si- Sodium Silicate levels

Si_0: Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,; 200 mg kg^{-1} soil; Si_3: 300 mg kg^{-1} soil

Figure 11. Effect of Moringa Seed Extract levels on Stem diameter (cm) [LSD value 0.4689, 0.3920, 0.3980, 0.3952and 0.7490at 30, 45, 60, 75 DAP and at harvest respectively

Combined effect of MSE and Si levels in terms of stem diameter of potato exposed significant variation among treatment combinations at 30, 45, 60 and 75 DAP (Appendix IX). It was remarked that the widest stem was recorded in M_3Si_3 (0.6790 cm), whereas the narrowest was recorded in M_0Si_0 (0.248 cm) at 30 DAP (table 9) .

Table 8. Effect of MSE and Si levels on Diameter of stem (cm) at different days of planting

Treatments	Diameter of stem (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Levels of MSE					
M_0	0.3404d	0.3941d	0.4300d	0.4343d	0.4433d
M_1	0.4822c	0.5037c	0.5194c	0.5268c	0.5323c
M_2	0.5550b	0.5729b	0.5893b	0.5964b	0.6011b
M_3	0.6053a	0.6189a	0.6336a	0.6403a	0.6455a
$LSD_{(0.05)}$	0.0395	0.0370	0.0356	0.0351	0.0347
Level of significance	**	**	**	**	**
CV(%)	11.18	9.96	9.19	8.98	8.76
Levels of Si					
Si_0	0.4627b	0.5038a	0.5336a	0.5407a	0.5464a
Si_1	0.4984ab	0.5218a	0.5389a	0.5434a	0.5499a
Si_2	0.5066a	0.5299a	0.5442a	0.5516a	0.5573a
Si_3	0.5153a	0.5341a	0.5556a	0.5619a	0.5684a
$LSD_{(0.05)}$	0.0395	0.0370	0.0356	0.0351	0.0347
Level of significance	NS	NS	NS	NS	NS
CV(%)	11.18	9.96	9.19	8.98	8.76

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 9. Combined Effect of MSE and Si levels on Diameter of stem (cm) at different days of planting

Treatments	Diameter of stem (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
M_0Si_0	0.248j	0.3460i	0.3755g	0.3758h	0.3890h
M_0Si_1	0.3148ij	0.3625hi	0.4363fg	0.4415gh	0.4475gh
M_0Si_2	0.3848hi	0.4238gh	0.4375fg	0.4443gh	0.4510gh
M_0Si_3	0.4135gh	0.4440fg	0.4690ef	0.4755fg	0.4815fg
M_1Si_0	0.4250f-h	0.4505fg	0.4708ef	0.4773fg	0.4855fg
M_1Si_1	0.4780e-g	0.4978e-g	0.5158de	0.5223ef	0.5288ef
M_1Si_2	0.4934ef	0.5105d-f	0.5382c-e	0.5445d-f	0.5493d-f
M_1Si_3	0.5095de	0.5320b-e	0.5463b-d	0.5525c-e	0.5588c-e
M_2Si_0	0.5165c-e	0.5345b-e	0.5467b-d	0.5550c-e	0.5600c-e
M_2Si_1	0.5533b-e	0.5820a-d	0.5963a-c	0.6023b-d	0.6055b-d
M_2Si2	0.5752a-d	0.5940a-c	0.6085a-c	0.6180a-c	0.6245a-c
M_2Si_3	0.5850a-d	0.5950a-c	0.6108ab	0.6193a-c	0.6245a-c
M_3Si_0	0.58a-c	0.6043a-c	0.6140ab	0.6207a-c	0.6250a-c
M_3Si_1	0.592a-c	0.6073ab	0.6195a	0.6263ab	0.6320ab
M_3Si_2	0.616ab	0.6248a	0.6370a	0.6430ab	0.6465ab
M_3Si_3	0.6377a	0.6498a	0.6670a	0.6728a	0.6790a
$LSD_{(0.05)}$	0.0789	0.0741	0.0711	0.0702	0.0693
Level of significance	NS	NS	NS	NS	NS
CV(%)	11.18	9.96	9.19	8.98	8.76

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

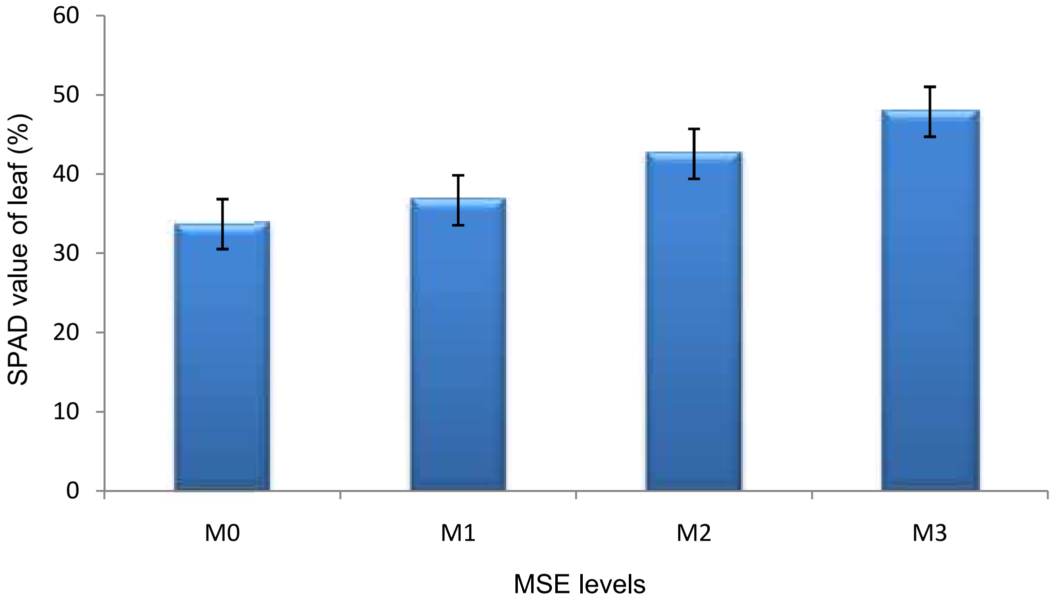
4.6 SPAD value of leaf

SPAD value of leaves was statistically significant ($P \leq 0.01$) by the influence of different MSE levels. Figure 11 showed that SPAD value of leaves was increased due to increment of MSE levels(Appendix XII). The maximum value was found in M_3 (48.63%) whereas the minimum value was found in M_0 (33.12%).

Si levels also significantly influence the SPAD value of leaves. Figure 13 showed that with increasing level of Si ,the SPAD value of leaves was increasing. The maximum value was found in Si_3 (42.09%) whereas the minimum value was found in Si_0 (38.26%).

Treatment combination had non-significant influence on the SPAD value of leaves. The maximum value was found in M_3Si_3 (51.04%) whereas the minimum value was found in M_0Si_0 (32.31%).

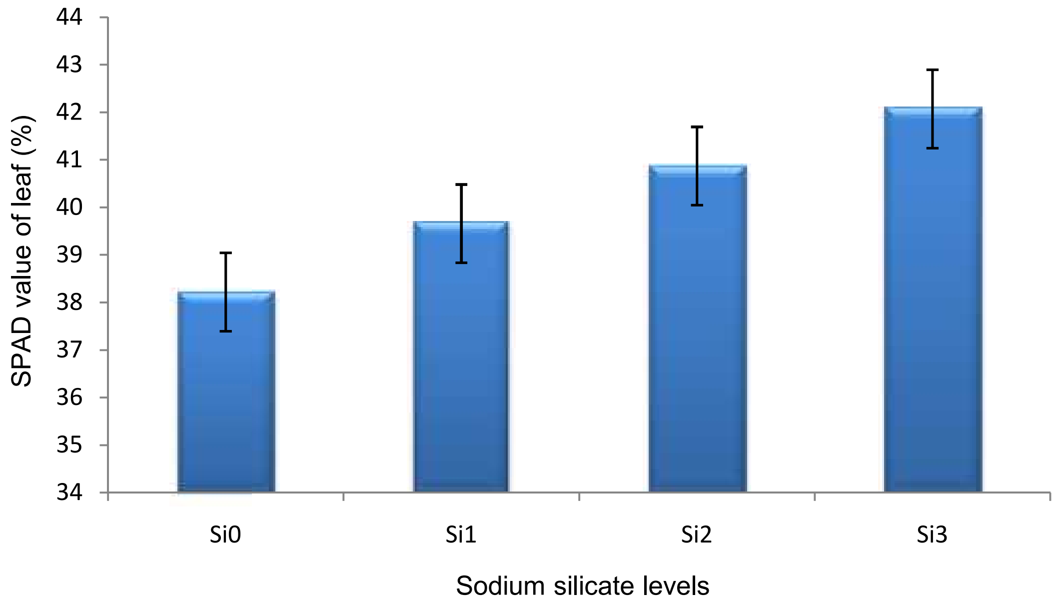
Similar trend of result was found by Howladar (2014), who observed that foliar spray of MLE significantly enhanced the SPAD value in leaves.



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 12. Effect of Moringa Seed Extract levels on SPAD value of leaf [LSD value 0.7223 at 30 DAP]

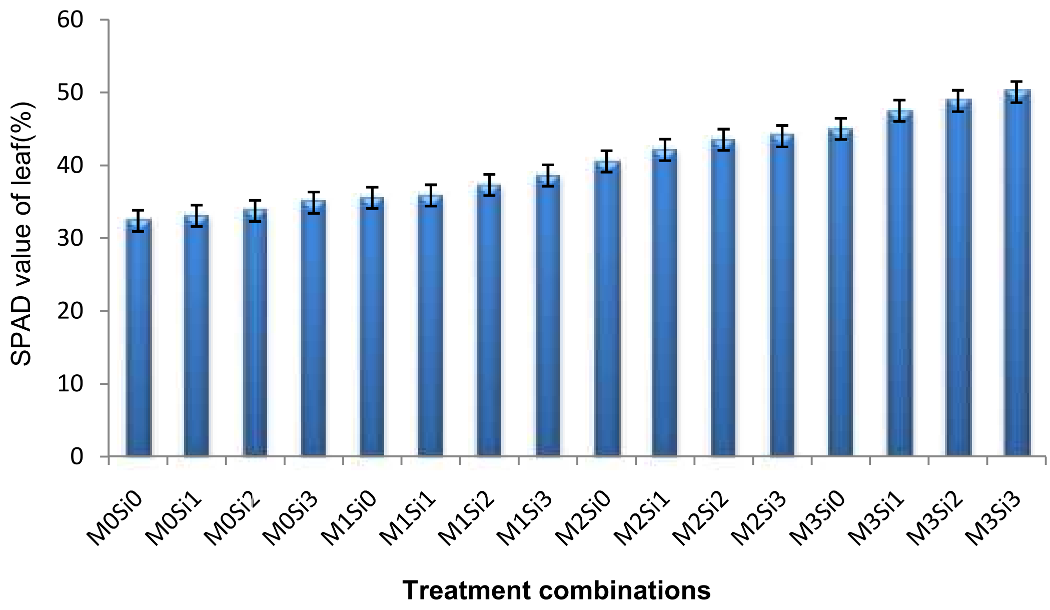


Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 13. Effect of Sodium silicate levels on SPAD value of leaf [LSD value 0.7223 at 30 DAP]



MSE- Moringa Seed Extract Si- Sodium Silicate

M_0: Control(0% MSE solution) Si_0:Control(0 mg kg ^{1} soil)

M_1; 3% MSE solution Si_1: 100 mg kg^{-1} soil;

M_2: 6% MSE solution $Si_{2:}$ 200 mg kg^{-1} soil;

M_3:, 9% MSE solution Si_3: 300 mg kg^{-1} soil

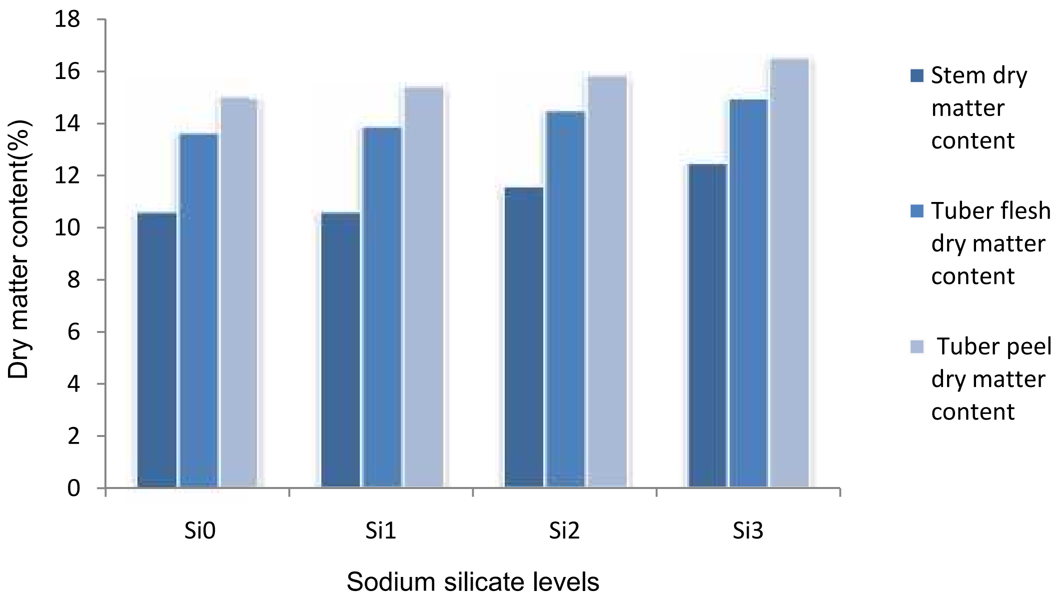
Figure 14 Combined effect of MSE and Sodium silicate levels on SPAD value of leaf

4.7 Stem dry matter content(%)

Stem dry matter content was statistically significantly influenced by different MSE levels(Appendix X). Figure 15 showed that dry matter in stems was increased with increasing levels of MSE. The maximum dry matter found in M_3(13.496 %) where as the minimum found in M_0(8.142 %).(Table 10).

Dry matter content in stems also significantly influenced by Si levels. The maximum dry matter found in Si_3 (12.510 %) where as the minimum found in S_0 (10.591%) (Figure 16).

Combinations of treatments were also significantly influenced the dry matter content. The maximum dry matter in stem was found in M_3Si_3 (14.263 %) which is statistically similar to M_3Si_2 (14.188 %), M_3Si_1 (13.388 %), M_3Si_0 (13.342 %) M_2Si_3 (13.250 %) and M_2Si_2 (13.085 %). Whereas the minimum dry content in stems was found in M_0Si_0 (6.920%) which is statistically similar to M_0Si_1 (7.600%) (Table11).



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 15. Effect of Sodium silicate levels on Stem, tuber and peel dry matter content (%)

4.8 Tuber flesh dry matter content(%)

Tuber flesh dry matter content significantly varied with the MSE levels . It was increased with incretion of the MSE levels (Appendix X). Figure 15 showed that the maximum dry matter found in M_3 (21.951%) where as the minimum found in M_0 (16.694 %).

Tuber flesh dry matter content also significantly varied with the Si levels . It was increased with incretion of the Sodium silicate levels. The maximum dry matter found in Si_3 (20.218%) where as the minimum found in Si_0 (18.959 %) (Table 10).

Combinations of treatments were also significantly influenced the dry matter content of tuber flesh. Figure 16 showed that the maximum dry matter in flesh was found in M_3Si_3 (22.255 %) which is statistically similar to M_3Si_2 (22.142%), M_3Si_1 (21.910%), and M_3Si_0 (21.495%). Whereas the minimum dry content in stems was found in M_0Si_0 (16.035%) which is statistically similar to M_0Si_1 (16.260%) (Table 11).

4.9 Tuber peel dry matter content(%)

Tuber peel dry matter content significantly varied with the MSE levels . It was increased with incretion of the MSE levels. Figure 15 showed that the maximum dry matter found in M_3 (22.669%) where as the minimum found in M_0 (18.763%).

Tuber peel dry matter content also significantly varied with the Si levels . It was increased with incretion of the Sodium silicate levels. Figure 16 showed that the maximum dry matter found in Si_3 (21.098 %) where as the minimum found in Si_0 (20.304%) (Table 10).

Combinations of treatments were also significantly influenced the dry matter content of tuber peel. The maximum dry matter in peel was found in M_3Si_3 (22.788%) which is statistically similar to M_3Si_2 (22.755%) and M_3Si_1 (22.690%). Whereas the minimum dry content in stems was found in M_0Si_0 (16.035%) which is statistically similar to M_0Si_1 (16.260%) (Table 11**).**

Table 10. Effect of MSE and Si levels on Dry matter content(%)

Treatments	Dry matter content(%)		
	Stem dry matter content(%)	Tuber flesh dry matter content(%)	Tuber peel dry matter content(%)
Levels of MSE			
M_0	8.142c	16.694d	18.763d
M_1	10.597b	18.801c	19.901c
M_2	13.076a	20.363b	21.348b
M_3	13.496a	21.951a	22.669a
$LSD_{(0.05)}$	0.7042	0.4006	0.0804
Level of significance	**	**	**
CV(%)	8.73	2.89	0.55
Levels of Si			
Si_0	10.591c	18.959c	20.304d
Si_1	10.611c	19.118bc	20.536c
Si_2	11.599b	19.514b	20.741b
Si_3	12.510a	20.218a	21.098a
$LSD_{(0.05)}$	0.7042	0.4006	0.0804
Level of significance	**	**	**
CV(%)	8.73	2.89	0.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 11. Combined Effect of MSE and Si levels on Dry Matter Content

Treatments	Dry Matter Content(%)		
	Stem Dry Matter Content(%)	Tuber Flesh Dry Matter Content(%)	Tuber Peel Dry Matter Content(%)
M_0Si_0	6.920g	16.035h	18.425l
M_0Si_1	7.600fg	16.260gh	18.488l
M_0Si_2	8.553ef	16.840g	18.860k
M_0Si_3	9.275e	17.642f	19.278j
M_1Si_0	9.495e	18.253ef	19.588i
M_1Si_1	9.905de	18.205ef	19.778h
M_1Si_2	11.113cd	19.005de	19.915h
M_1Si_3	12.095bc	19.740cd	20.322g
M_2Si_0	12.320bc	20.053c	20.760f
M_2Si_1	12.455bc	20.098c	21.190e
M_2Si_2	13.085ab	20.070c	21.435d
M_2Si_3	13.250ab	21.233b	22.005c
M_3Si_0	13.342ab	21.495ab	22.445b
M_3Si_1	13.388ab	21.910ab	22.690a
M_3Si_2	14.188a	22.142a	22.755a
M_3Si_3	14.263a	22.255a	22.788a
$LSD_{(0.05)}$	1.4084	0.8013	0.1608
Level of significance	**	**	**
CV(%)	8.73	2.89	0.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.10 Days to maturity (Visual observation)

When leaf of potato plant was 60% yellow the plant considered as 100% mature. Days to maturity was significantly affected by MSE levels (Appendix V). Duration of plant maturity decreased with the increasing of MSE levels. The maximum period required to maturity in M_0 (86.578days) ,while minimum period required in M_3 (81.500 days).

Sodium silicate had also significant influence on days to maturity. The maximum period required to maturity in Si_0 (84.539days) which is statistically similar to Si_1(84.413days), while minimum period required in Si_3 (83.524days) , which is statistically similar to Si_2 (83.141 days).

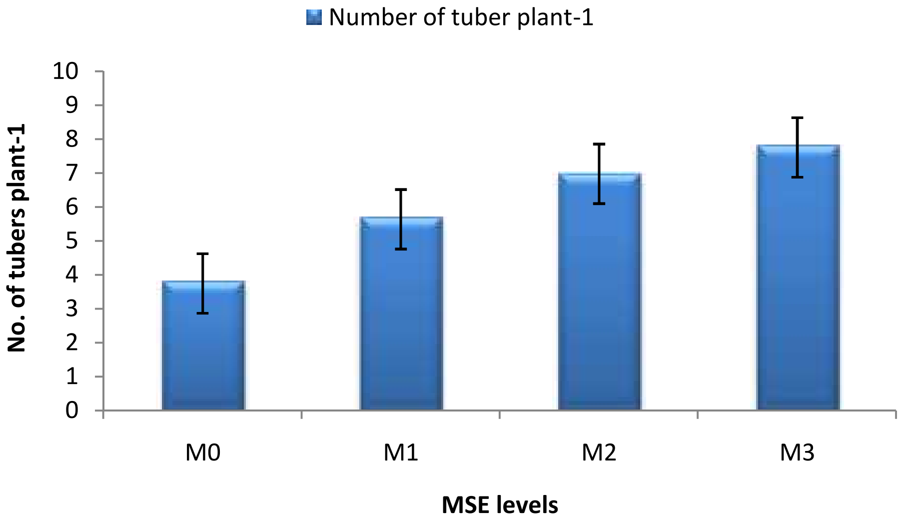
Days to maturity of potato tubers was significantly influenced by combined effects of MSE and Si levels (Appendix V). The treatment combination M_0Si_0 required minimum duration (87.650 days) for maturity which was statistically similar to M_0Si_1 (87.588 days)where maximum recorded in M_3Si_3 (81.228 days) which was statistically similar to M_3Si_2 (81.572), M_3Si_1 (81.293) and M_3Si_0 (81.907) .

4.11 Number of tubers plant^{-1}

Different levels of MSE varied significantly($P \leq 0.05$) in terms of number of tubers plant^{-1} of potato. Figure 16 showed that the maximum number of tuber plant^{-1} (7.7587) was observed from M_3, while the minimum number (3.7481) was recorded from M_0 (Table 12).

Number of tubers plant^{-1} showed statistically significant ($P \leq 0.01$) differences due to different levels of Si. Figure 17 showed that the maximum number of tubers plant^{-1} (6.4919) was recorded from Si_3 ,whereas the minimum number (5.5419) was observed from Si_0.

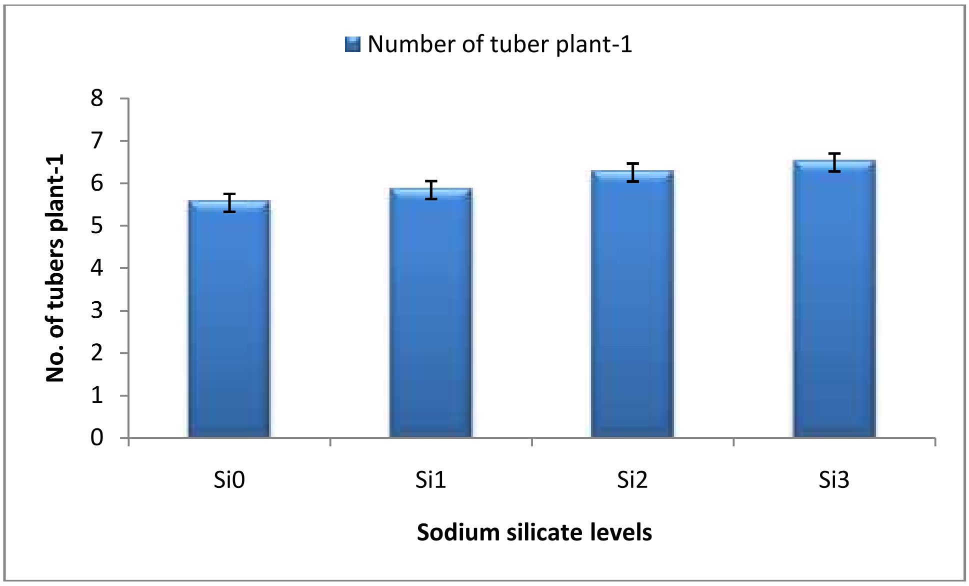
Statistically significant variation was recorded in terms of number of tubers plant^{-1} of potato due to the combined effect of MSE and Si levels . The maximum number of tubers plant^{-1} (8.1775) was found from M_3Si_3, which is statistically similar to M_3Si_2 (7.8875) , while the minimum number (3.0675) was observed from M_0Si_0 treatment combination, which is statistically sililar to M_0Si_1 (3.3475) (Table 13).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 16. Effect of Moringa Seed Extract levels on Number of tubers plant^{-1}



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;
Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 17. Effect of Sodium silicate levels on Number of tubers plant^{-1}

4.12 Average weight of individual tuber plant^{-1}(g)

Statistically significant variation was recorded in terms of average weight of individual potato tuber due to levels of MSE(Appendix X). Table 12 showed that the highest average weight of individual tuber (44.438 g) was recorded from M3 which was statistically similar (42.625g) to M2, whereas the lowest (37.125g) was found from M0 (Figure 18).

Different levels of Sodium silicate showed statistically significant differences(Appendix X) in terms of average weight of individual potato tubers (Appendix X) . Table 12 showed that the highest average weight of individual tuber (42.563g) was recorded from Si3 which was statistically similar (41.625g and 40.750 g, respectively) to S2 and S1, while the lowest (39.813g) was found from Si0 (Figure 19)

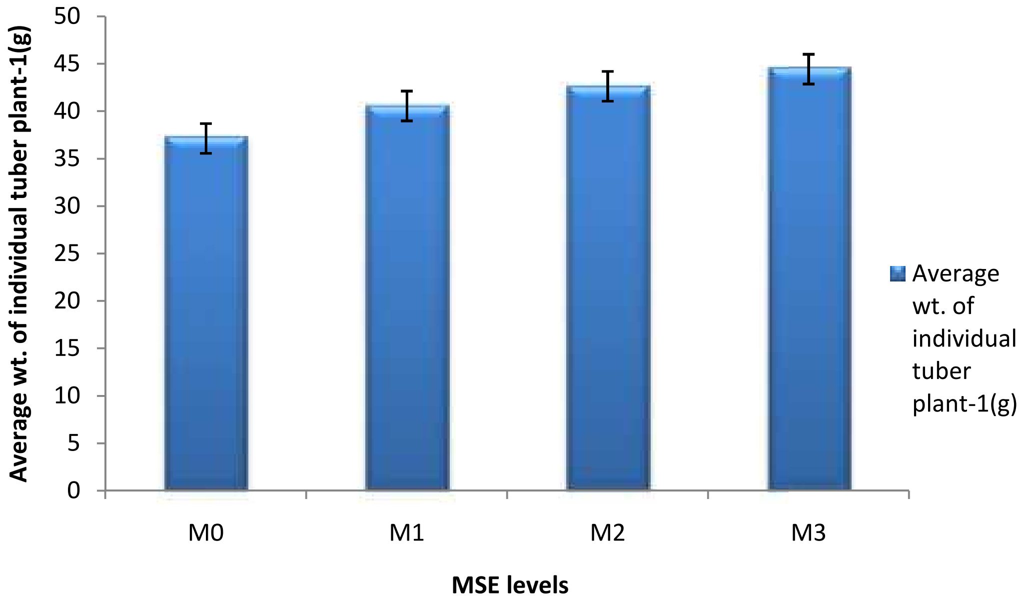
Average weight of individual potato tuber showed statistically significant differences due to the combined effect of different levels of MSE and Si. Table 3 showed that the highest average weight of individual potato tubers (45.250g) was found from M_3Si_3,which was statistically similar (44.250g, 45.250g, 43.000g, 44.750g, 42.750g, 42.000g, 41.000g, 41.750g and 41.500g, respectively) to M_3Si_2, M_3Si_1, M_3Si_0, M_2Si_3, M_2Si_2, M_2Si_1, M_2Si_0,M_1Si_3 and M_1Si_2. Whereas the lowest (35.500g) was observed from M_0Si_0 treatment combination, which was statistically similar (36.500g, 38.000g, 38.500g, 39.750g and 39.250g respectively) to M_0Si_1, M_0Si_2, M_0Si_3, M_1Si_0 and M_1Si_1.

4.13 Weight of tubers plant^{-1}(g)

Statistically significant variation was recorded in terms of weight of potato tubers plant^{-1} due to different levels of MSE. Table 12 showed that the highest weight of potato tubers (432.73 g) was recorded from M_3, while the lowest weight (119.21g) was found from M_0. Elrys *et al.* (2018) also found similar trend by using MSE through drip irrigation (Figure 18).

Different levels of Si showed statistically significant differences in terms of weight of potato tubers plant^{-1}. Table 12 showed that the highest weight of potato tubers (299.92 g) was recorded from Si_3, while the lowest weight (222.19) was found from Si_0. Elrys *et al.* (2018) also found similar trend by using MSE through drip irrigation (Figure 19).

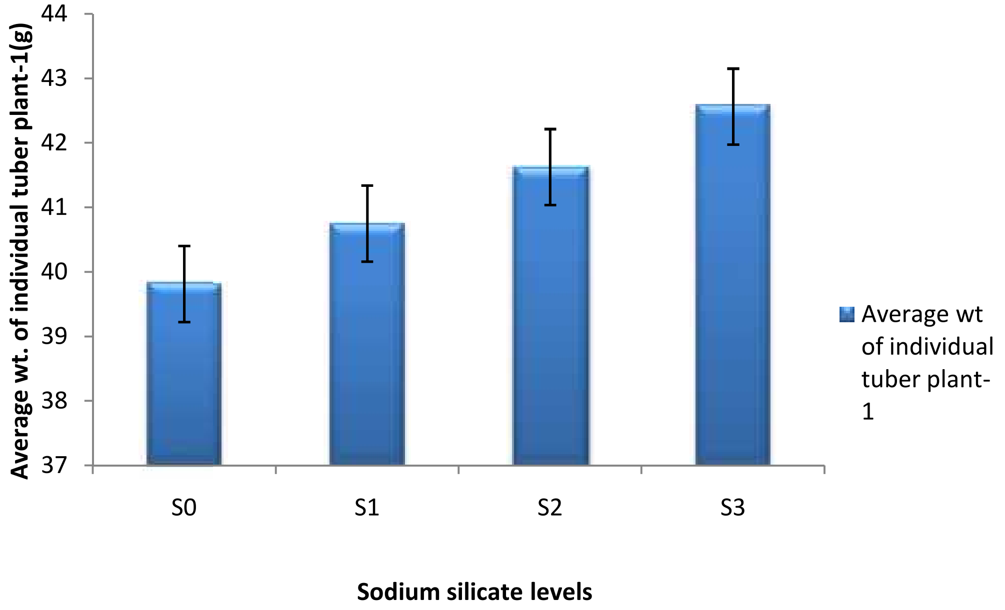
Weight of potato tubers plant^{-1} showed statistically significant differences due to the combined effect of different levels of MSE and Si. Table 13 showed that the highest weight of potato tubers (476.47g) was found from M_3Si_3, which was statistically similar (451.59g) to M_3Si_2. Whereas the lowest weight (75.48g) was observed from M_0Si_0 treatment combination, which was statistically similar (103.68g) to M_0Si_1.



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 18. Effect of MSE levels on Average wt. of individual tuber plant^{-1}(g)

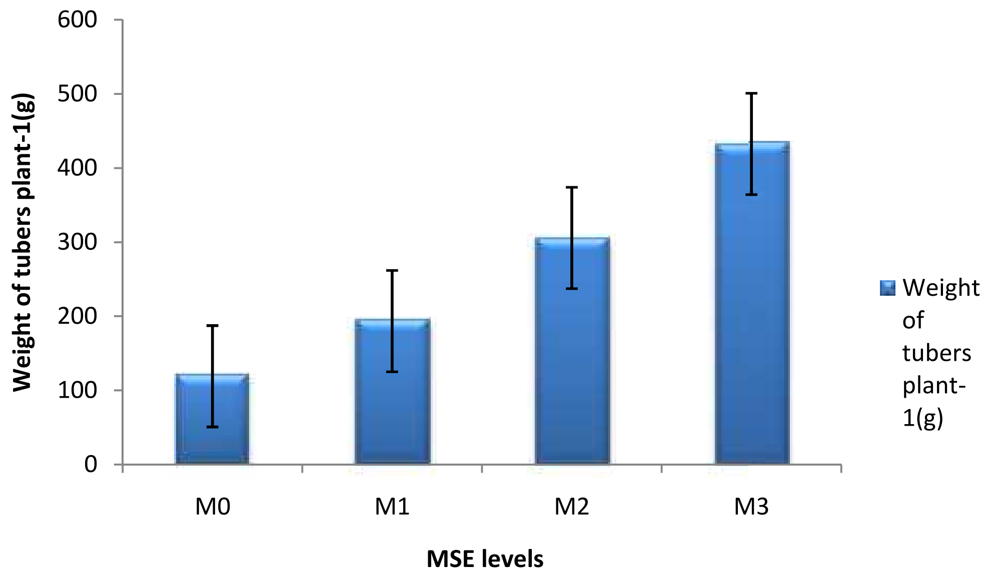


Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 19. Effect of Sodium silicate levels on Average wt. of individual tuber $plant^{-1}$(g)

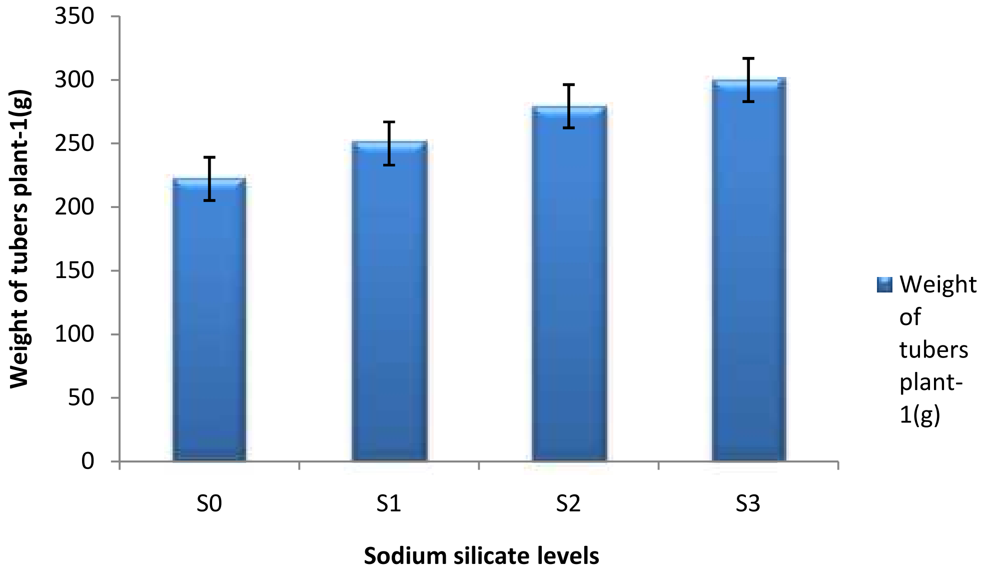


MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;

M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 20. Effect of Moringa Seed Extract levels on Weight of tubers $plant^{-1}$(g)



Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 21. Effect of Sodium silicate levels on Average wt. of individual tuber plant-1(g)

Table 12. Effect of MSE and Si levels on Number and Yield of tuber plant^{-1}

Treatments	Number and Yield of tuber plant^{-1}		
	Number of tubers plant^{-1}	Average weight of individual tuber (g)	Weight of tubers plant^{-1}(g)
Levels of MSE			
M_0	3.7481d	37.125c	119.21d
M_1	5.6419c	40.563b	193.61c
M_2	6.9813b	42.625ab	305.80b
M_3	7.7587a	44.438a	432.73a
$LSD_{(0.05)}$	0.1670	2.1547	14.589
Level of significance	*	*	*
CV(%)	3.89	7.35	7.79
Levels of Si			
Si_0	5.5419d	39.813b	222.19d
Si1	5.8437c	40.750ab	249.99c
Si_2	6.2525b	41.625ab	279.26b
Si_3	6.4919a	42.563a	299.92a
$LSD_{(0.05)}$	0.1670	2.1547	14.589
Level of significance	**	**	**
CV(%)	3.89	7.35	7.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly
** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 13. Combined Effect of MSE and Si levels on Number and Yield of tuber plant

Treatments	Number and Yield of tuber plant^{-1}		
	Number of tuber plant^{-1}	Average weight of individual tuber (g)	Weight of tuber plant^{-1}(g)
M_0Si_0	3.0675k	35.500e	75.48i
M_0Si_1	3.3475k	36.500e	103.68i
M_0Si_2	3.9675j	38.000de	132.91h
M_0Si_3	4.6100i	38.500cde	164.77g
M_1Si_0	5.1225h	39.750b-e	165.67g
M_1Si_1	5.4900g	39.250b-e	189.62fg
M_1Si_2	5.8200fg	41.500a-d	202.55f
M_1Si_3	6.1350f	41.750a-d	216.62f
M_2Si_0	6.5575e	41.000a-d	254.15e
M_2Si_1	6.9875d	42.000a-d	297.27d
M_2Si2	7.0450cd	42.750abc	329.97c
M_2Si_3	7.3350bc	44.750a	341.83c
M_3Si_0	7.4200b	43.000ab	393.46b
M_3Si_1	7.5500b	45.250a	409.40b
M_3Si_2	7.8875a	44.250a	451.59a
M_3Si_3	8.1775a	45.250a	476.47a
$LSD_{(0.05)}$	0.3341	4.3093	29.177
Level of significance	**	**	NS
CV(%)	3.89	7.35	7.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

* indicates 5% level of significance

NS indicates Non-significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

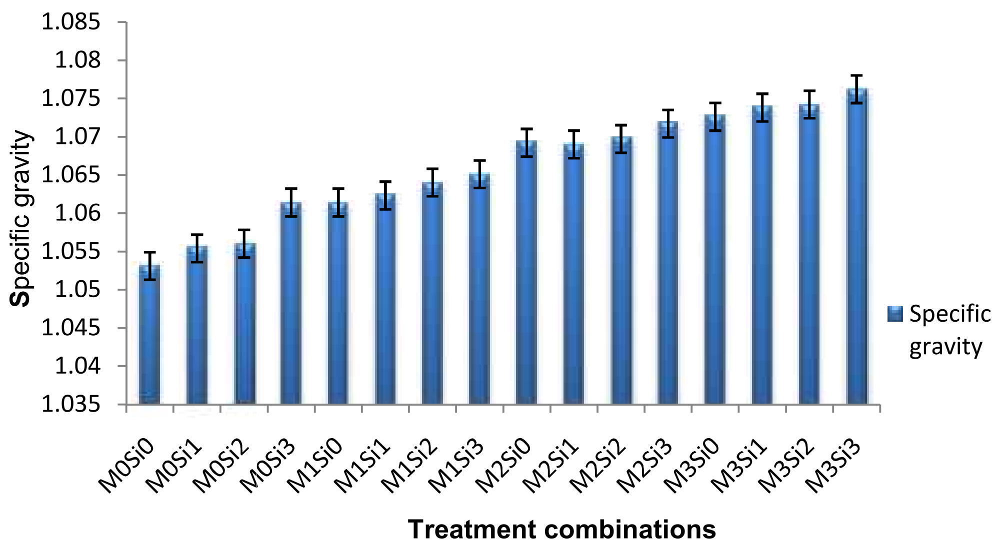
Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.14 Specific gravity of tuber

Different MSE levels influenced significantly in terms of specific gravity of potato tubers. Table 14 showed that the highest specific gravity of potato tubers (1.0742) was found from M_3 and the lowest (1.0557) was observed from M_2 (Figure 20).

Specific gravity of potato tubers showed statistically significant differences due to different levels of Si. Table 14 showed that the highest specific gravity of potato tubers (1.0678) was found from Si_3, which was statistically similar (1.0660 and 1.0652) to Si_2 and Si_1,while the lowest (1.0641) was observed from Si_0, which was statistically similar (1.0652) to Si_1. Elrys *et al.*, (2018) reported that specific gravity increased with increasing Si levels.

Treatment combinations had statistically influenced on sp. gravity. The height value was obtained (1.0762) in M_3Si_3, which was statistically similar (1.0742, 1.0738, 1.0726,1.0717 and 1.0697) to M_3Si_2, M_3Si_1, M_3Si_0, M_2Si_3 ad M_2Si_2. And the lowest was found (1.0531) in M_0Si_0, which was statistically similar (1.0554, 1.0560 and 1.0582)to M_0Si_1, M_0Si_2 and M_0Si_3 (Table 15).



MSE-Moringa Seed extract levels	Si- Sodium Silicate levels
M_0: Control(0% MSE solution)	Si_0:Control(0 mg kg^{-1} soil)
M_1: 3% MSE solution;	Si_1: 100 mg kg^{-1} soil;
M_2: 6% MSE solution	Si_2;200 mg kg^{-1} soil;
M_3: 9% MSE solution	Si_3:300 mg kg^{-1} soil

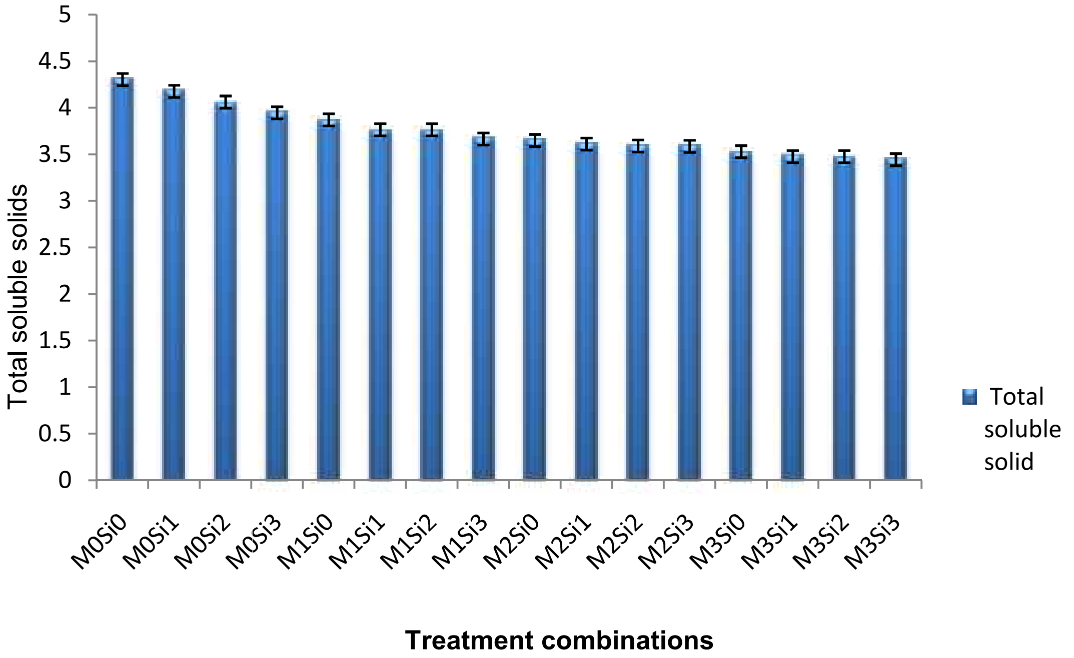
Figure 22. Combined effect of MSE and Sodium silicate levels on Specific gravity

4.15 Total soluble solid of tuber

Statistically significant variation was recorded in terms of TSS of potato tubers due to different levels of MSE. Table 14 showed that the The highest TSS in potato tubers (4.12310Brix) was recorded from M_0, whereas the lowest (3.4969 0Brix) was found M_3 , which is statistically similar(3.5988) to M_2 .

TSS of potato tubers showed statistically significant differences due to different levels of Si. Table 14 showed that the highest TSS in potato tubers (3.8388 0Brix) was recorded from Si_0 which was statistically similar (3.7631 0Brix) to Si_1 and the lowest (3.6712 0Brix) was observed from Si_3.

Statistically significant differences was observed in terms of TSS in potato tubers due to the combined effect of different levels of MSE and Si. Table 14 showed that the highest TSS in potato tubers (4.3050 ^{0}Brix) was observed from M_0Si_0, which was statistically similar (4.1775^{0}Brix and 4.0625 ^{0}Brix) to M_0Si_1 and M_0Si_2, whereas the lowest (3.6650 ^{0}Brix) from M_3Si_3 treatment combination, which was statistically similar (3.6500^{0}Brix, 3.6100^{0}Brix, 3.5900 ^{0}Brix,3.5875 ^{0}Brix, 3.5300^0 Brix, 3.4475^{0}Brix, 3.4775 ^{0}Brix and 3.4450^{0}Brix) to M_3Si_2, M_3Si_1 ,M_3Si_0, M_2Si_3 ,M_2Si_2 M_2Si_1, M_2Si_0 and M_1Si_3.



MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Figure 23. Combined effect of MSE and Sodium silicate levels on Total soluble solid

Table 14. Effect of MSE and Si levels on Specific gravity and Total soluble solid

Treatments	Specific gravity and Total soluble solid	
	Specific gravity	Total soluble solid
Levels of MSE		
M_0	1.0557d	4.1231a
M_1	1.0632c	3.7631b
M_2	1.0699b	3.5988c
M_3	1.0742a	3.4969c
$LSD_{(0.05)}$	0.00342	0.1288
Level of significance	**	**
CV(%)	0.24	4.83
Levels of Si		
Si_0	1.0641b	3.8388a
Si_1	1.0652ab	3.7631ab
Si_2	1.0660ab	3.7088b
Si_3	1.0678a	3.6712b
$LSD_{(0.05)}$	0.00342	0.1288
Level of significance	*	*
CV(%)	0.24	4.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance *indicates 5% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 15. Combined Effect of MSE and Si levels on Specific gravity and Total soluble solid

Treatments	**Specific gravity and Total soluble solid**	
	Specific gravity	Total soluble solid
M_0Si_0	1.0531j	4.3050a
M_0Si_1	1.0554ij	4.1775ab
M_0Si_2	1.0560hij	4.0625abc
M_0Si_3	1.0582g-j	3.9475bcd
M_1Si_0	1.0614fghi	3.8725cde
M_1Si_1	1.0623e-h	3.7650def
M_1Si_2	1.0640d-g	3.7650def
M_1Si_3	1.0651c-f	3.6650efg
M_2Si_0	1.0692bcd	3.6500efg
M_2Si_1	1.0690b-e	3.6100fg
M_2Si_2	1.0697a-d	3.5900fg
M_2Si_3	1.0717abc	3.5875fg
M_3Si_0	1.0726ab	3.5300fg
M_3Si_1	1.0738ab	3.4775g
M_3Si_2	1.0742ab	3.4775g
M_3Si_3	1.0762a	3.4450g
$LSD_{(0.05)}$	0.006852	0.2032
Level of significance	**	**
CV(%)	0.45	4.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.16 Marketable and non marketable yield

The results indicated that there was significant difference in the effect of MSE on potato in respect of production of marketable and non marketable tubers on the basis of % by number. It was observed that numerically maximum marketable potato produce in M_3 (63.152%) where the minimum was recorded from M_0 (34.678%) and numerically maximum non marketable tuber produced in M_0 (65.322%) where the minimum produced in M_3 (36.848%) (Table 16).

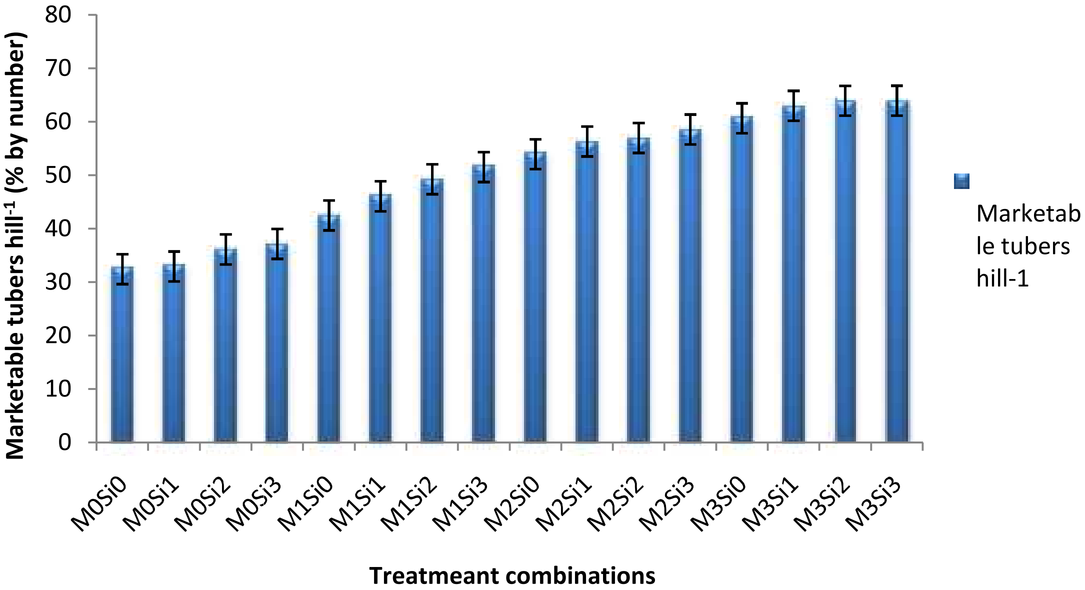
On the basis of % by weight the marketable and non marketable tuber plant^{-1} was significantly varied among different MSE levels. Maximum % by weight marketable potato produced in M_3 (75.486%) , where the minimum produced in M_0 (49.108%) . The Maximum % by weight non marketable potato produced in M_0 (50.893%) ,where the minimum produced in M_3 (25.514%) (Figure 22).

Effect of Si levels on marketable and non marketable tubers (% by number) was - significant (Appendix XI). It was observed that numerically the maximum marketable potato (% by number) produce in Si_3 (53.070%) where minimum was recorded in Si_0 (47.392%) . Numerically the maximum non-marketable potato (% by number) produce in Si_0 (52.608%) where minimum was recorded in Si_3 (46.930%) (Table 16).

On the basis of marketable and non marketable tubers plant^{-1} (% by weight) was insignificant among different Si levels (Appendix XI). Numerically the maximum number of marketable tubers (% by weight) was recorded from Si_3 (67.611%) , where minimum was recorded from Si_0 (58.100%) . Numerically the maximum number of non-marketable tubers (% by weight) was recorded from Si_3 (32.389%) , where minimum was recorded from Si_0 (41.900%) .

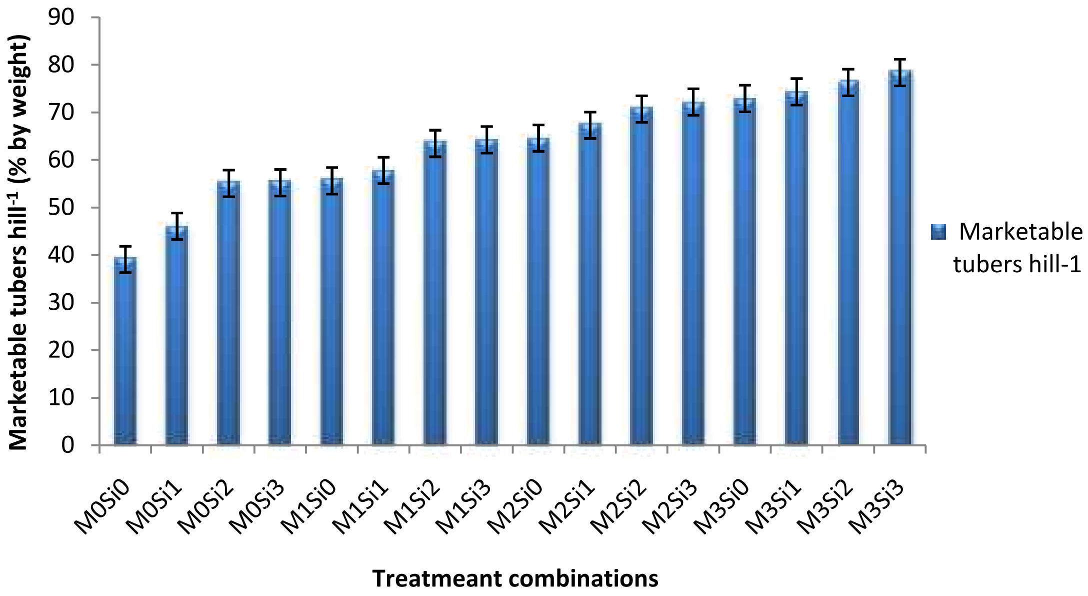
Combined effects of different levels of MSE and Si levels showed statistically significant variation on grade of tubers on the basis of marketable tubers % by number (Appendix XI). The maximum marketable tuber (% by number) was recorded from M_3Si_3 (64.960%) which was statistically similar to M_3S_2 (63.958%) and the minimum was found in M_0S_0 (32.438%) which was statistically similar to M_0Si_1 (32.950%), (Table17).

The maximum non marketable tuber (% by weight) was recorded from M_0Si_0 (60.310%), where the minimum (21.608%) was found in M_3Si_3 which was statistically similar to M_3Si_2 (23.690%) (Table 17).



MSE- Moringa Seed Extract	Si- Sodium Silicate
M_0: Control(0% MSE solution)	Si_0:Control(0 mg kg ^{1} soil)
M_1; 3% MSE solution	Si_1: 100 mg kg^{-1} soil;
M_2: 6% MSE solution	$Si_{2:}$ 200 mg kg^{-1} soil;
M_3:, 9% MSE solution	Si_3: 300 mg kg^{-1} soil

Figure 24. Combined effect of MSE and Sodium silicate levels on Marketable tubers $hill^{-1}$(% by number)



MSE- Moringa Seed Extract	Si- Sodium Silicate
M_0: Control(0% MSE solution)	Si_0:Control(0 mg kg ^{1} soil)
M_1; 3% MSE solution	Si_1: 100 mg kg^{-1} soil;
M_2: 6% MSE solution	$Si_{2:}$ 200 mg kg^{-1} soil;
M_3:, 9% MSE solution	Si_3: 300 mg kg^{-1} soil

Figure 25. Combined effect of MSE and Sodium silicate levels on Marketable tubers hill-1(% by weight)

Table 16 Effect of MSE and Si levels on the Grade(% by number and % by weight)

Treatments	Grade(% by number and % by weight)			
	Marketable tubers hill^{-1}(% by number)	Non-marketable tubers hill^{-1}(% by number)	Marketable tubers hill^{-1}(% by weight)	Non-marketable tubers hill^{-1}(% by weight)
Levels of MSE				
M_0	34.678d	65.322a	49.108d	50.893a
M_1	47.348c	52.652b	60.174c	39.826b
M_2	56.464b	43.536c	68.694b	31.306c
M_3	63.152a	36.848d	75.486a	24.514d
$LSD_{(0.05)}$	0.8705	0.8705	1.5022	1.5022
Level of significance	**	**	**	**
CV(%)	2.42	2.47	3.33	5.76
Levels of Si				
Si_0	47.392d	52.608a	58.100c	41.900a
Si_1	49.593c	50.407b	61.368b	38.632b
Si_2	51.588b	48.412c	66.382a	33.618c
Si_3	53.070a	46.930d	67.611a	32.389c
$LSD_{(0.05)}$	0.8705	0.8705	1.5022	1.5022
Level of significance	**	**	**	**
CV(%)	2.42	2.47	3.33	5.76

** In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
Si_2: 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 17. Combined effect of MSE and Si levels on the Grade(% by number and % by weight)

Treatments	Grade(% by number and % by weight)			
	Marketable tubers $hill^{-1}$(% by number)	Non-marketable tubers $hill^{-1}$(% by number)	Marketable tubers $hill^{-1}$(% by weight)	Non-marketable tubers $hill^{-1}$(% by weight)
M_0Si_0	32.438l	67.562a	39.690i	60.310a
M_0Si_1	32.950l	67.050a	46.075h	53.925b
M_0Si_2	36.145k	63.855b	55.058g	44.942c
M_0Si_3	37.180k	62.820b	55.190g	44.810c
M_1Si_0	42.495j	57.505c	55.607g	44.393c
M_1Si_1	46.082i	53.918d	57.790g	42.210c
M_1Si_2	49.262h	50.738e	63.465f	36.535d
M_1Si_3	51.552g	48.447f	64.250f	35.750d
M_2Si_0	53.952f	46.048g	64.595ef	35.405de
M_2Si_1	56.330e	43.670h	67.290e	32.710e
M_2Si2	56.988de	43.013hi	70.695d	29.305f
M_2Si_3	58.588d	41.412i	72.195cd	27.805fg
M_3Si_0	60.683c	39.318j	72.925cd	27.075fg
M_3Si_1	63.010b	36.990k	74.315bc	25.685gh
M_3Si_2	63.958ab	36.043kl	76.310ab	23.690hi
M_3Si_3	64.960a	35.040l	78.393a	21.608i
$LSD_{(0.05)}$	1.7409	1.7409	3.0044	3.0044
Level of Significance	**	**	**	**
CV(%)	2.42	2.47	3.33	5.76

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

4.17 Cadmium content of tuber flesh (mgkg^{-1} dw)

Araujo *et al.* (2013) studied the bioremediation of waters contaminated with heavy metals using moringa oleifera seeds as biosorbent. The study revealed that *M. oleifera* seeds have been most widely applied as a coagulant agent. Many studies have been performed in order to explore other potential applications of this material, especially in the removal of metals from aqueous systems. The seed reportedly contains 4-(α-L-rhamnopyranosyloxy)-benzylglucosinolate in high concentrations. Every glucosinolate contains a central carbon atom which is bonded to the thioglucose group via a sulfur atom and to a sulfate group via a nitrogen atom. These functional groups containing sulfur and nitrogen are good metal sequesters from aqueous solution. Bio-sorption by dead biomass or by some molecules and their active groups is a passive process based mainly on the affinity between the biosorbent and the sorbate. In this case, the metal is sequestered by chemical sites naturally present in the biomass. The diagram illustrates the main steps in this process (Figure 26).

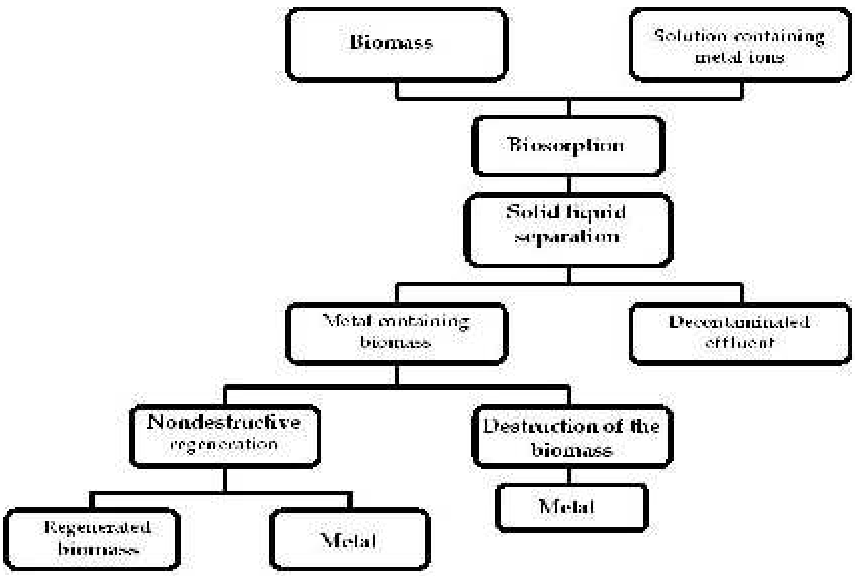


Figure 26 Main steps in bio-sorption process (Araujo *et al,*. 2013)

The mechanisms associated with heavy metal bio-sorption by biomass are still not clear; however, this process is not based on a single mechanism. Since metals may be present in the aquatic environment in dissolved or particulate forms, they can be dissolved as free hydrated ions or as complex ions chelated with inorganic ligands, or they may be complexed with organic ligands. Metal sequestration occurs through complex mechanisms, including ion-exchange and complexation, and it is quite possible that at least some of these mechanisms act simultaneously to varying degrees depending on the biomass, the metal ion and the solution environment.

Cadmium content was significantly varied by the levels of MSE. The concentration of Cd was below the maximum permissible limit(1 mgkg^{-1} dw) for consumption in food accept in M_0. The minimum Cd content obtained in M_3 (0.0389 mgkg^{-1} dw) whereas the maximum in M_0(1.1541 mgkg^{-1} dw).

Sodium silicate levels also significantly influence on the Cd content. The minimum Cd content obtained in Si_3 (0.3394 mgkg^{-1} dw) whereas the maximum in Si_0(0.7759 mgkg^{-1} dw).

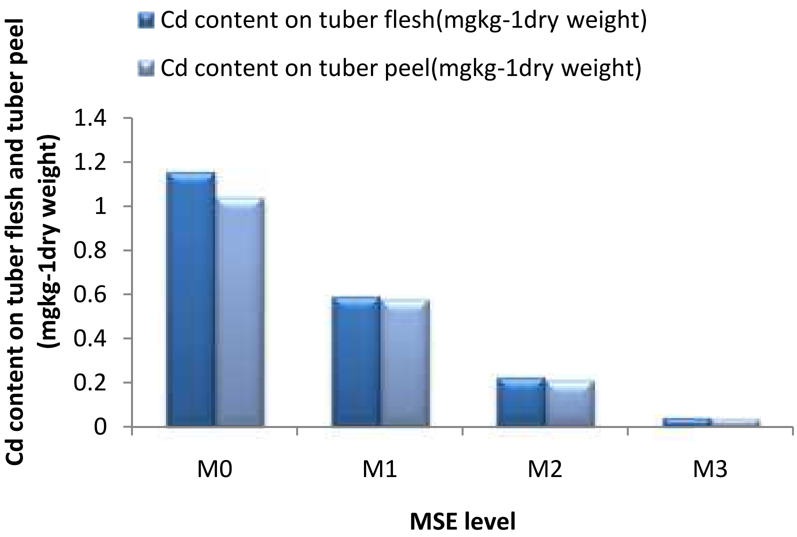
Combined effect of MSE and Si levels also had significant influence on on the Cd content. The minimum Cd content obtained in M_3Si_3 (0.0055 mgkg^{-1} dw) , which was also statistically similar(0.0225 mgkg^{-1} dw) , whereas the maximum in M_0Si_0 (1.9728 mgkg^{-1} dw). Elrys *et al.* (2018) observed similar trend of result for using MSE.

4.18 Cadmium content of tuber peel (mg kg^{-1} dw)

Cadmium content was significantly varied by the levels of MSE(Appendix XII). The concentration of Cd was below the maximum permissible limit(1mgkg^{-1}dw) for consumption in food. Table 18 showed that the minimum Cd content of tuber peel was obtained in M_3 (0.3276 mgkg^{-1}dw) whereas the maximum in M_0(0.6565 mgkg^{-1} dw) (Figure 25).

Sodium silicate levels also significantly influence on the Cd content. Table 18 showed that the concentration of Cd was below the maximum permissible limit(1 mgkg^{-1} dw) for consumption in food accept in Si_0. The minimum Cd content of tuber peel was obtained in Si_3 (0.0329 mgkg^{-1}dw) whereas the maximum in Si_0(1.0387 mgkg^{-1}dw) (Figure 26).

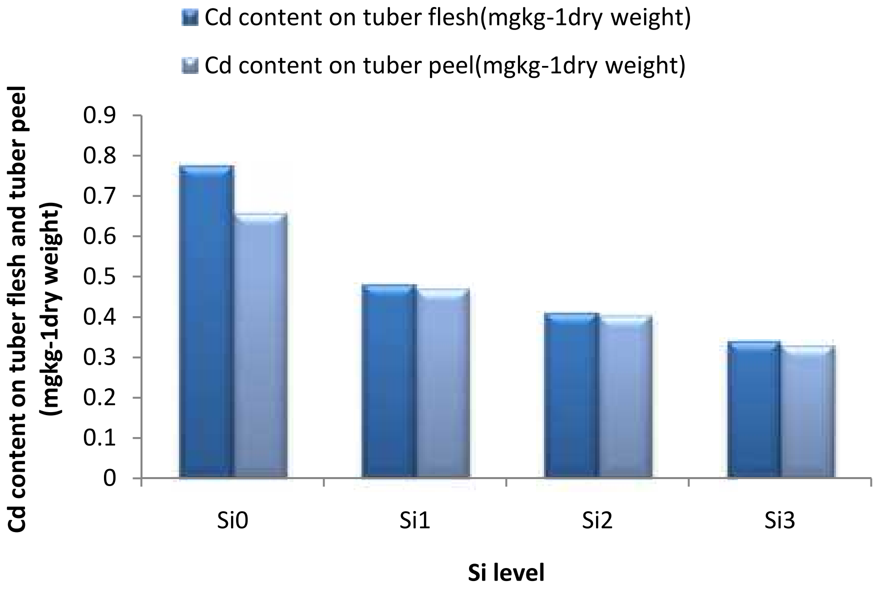
Combined effect of MSE and Si levels also had significant influence on on the Cd content. Table 19 showed that the minimum Cd content of tuber peel was obtained in M_3Si_3 (0.0025 mgkg^{-1}dw) , which was also statistically similar(0.0165 mgkg^{-1}dw) , whereas the maximum in M_0Si_0 (1.5342 $mgkg^{-1}dw$). Elrys et al., (2018) observed similar trend of result for using sodium silicate (Figure 27).



MSE- Moringa Seed Extract levels

M_0: Control(0% MSE solution) M_1; 3% MSE solution;
M_2: 6% MSE solution M_3:, 9% MSE solution

Figure 27. Effect of Moringa Seed Extract levels on Cd content on tubers and peel [LSD value: 0.0101 and 0.0107 for tuber and peel respectively]

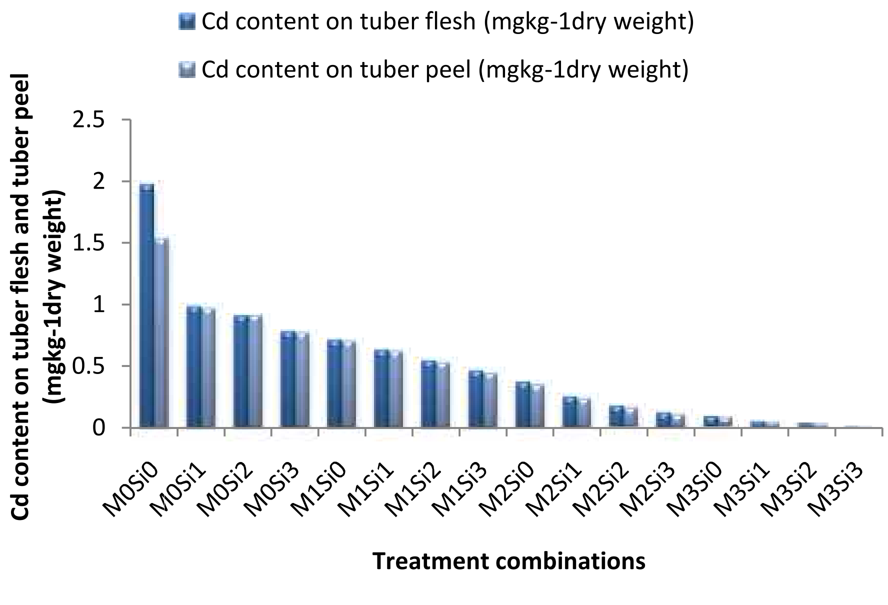


Si- Sodium Silicate levels

Si_0:Control(0 mg kg^{-1} soil) ; Si_1: 100 mg kg^{-1} soil;

Si_2,;200 mg kg^{-1} soil; Si_3:300 mg kg^{-1} soil

Figure 28. Effect of Sodium silicate levels on Cd content on tubers and peel [LSD value: 0.0101 and 0.0107 foe tuber and peel respectively]



MSE-Moringa Seed extract levels — Si- Sodium Silicate levels

M_0: Control(0% MSE solution) — Si_0:Control(0 mg kg^{-1} soil

M_1: 3% MSE solution; — Si_1: 100 mg kg^{-1} soil;

M_2: 6% MSE solution — Si_2,;200 mg kg^{-1} soil;

M_3: 9% MSE solution — Si_3:300 mg kg^{-1} soil

Figure 29. Combined effect of MSE and Si levels on the Cd content of tuber flesh and tuber peel (mg kg^{-1} dw)

Table 18. Effect of MSE and Si levels on Cd content on tuber flesh and tuber peel(mgkg^{-1}dry weight)

Treatments	Cd content on tuber flesh and tuber peel (mgkg^{-1}dry weight)	
	Cd content on tuber flesh(mgkg^{-1}dry weight)	Cd content on tuber peel(mgkg^{-1}dry weight)
Levels of MSE		
M_0	1.1541a	1.0387a
M_1	0.5799b	0.5659b
M_2	0.2231c	0.2081c
M_3	0.0389d	0.0329d
$LSD_{(0.05)}$	0.0101	0.0107
Level of significance	**	**
CV(%)	2.84	3.25
Levels of Si		
Si_0	0.7759a	0.6565a
Si_1	0.4751b	0.4632b
Si_2	0.4056c	0.3983c
Si_3	0.3394d	0.3276d
$LSD_{(0.05)}$	0.0101	0.0107
Level of significance	**	**
CV(%)	2.84	3.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

Table 19. Combined Effect of MSE and Si levels on Cd content on tuber flesh and tuber peel

Treatments	Cd content on tuber flesh and tuber peel ($mgkg^{-1}$dry weight)	
	Cd content on tuber flesh ($mgkg^{-1}$dry weight)	Cd content on tuber peel ($mgkg^{-1}$dry weight)
M_0Si_0	1.9728a	1.5342a
M_0Si_1	0.9833b	0.9685b
M_0Si_2	0.8933c	0.8972c
M_0Si_3	0.7673d	0.7550d
M_1Si_0	0.6972e	0.6865e
M_1Si_1	0.6168f	0.6052f
M_1Si_2	0.5427g	0.5287g
M_1Si_3	0.4628h	0.4433h
M_2Si_0	0.3560i	0.3355i
M_2Si_1	0.2503j	0.2363j
M_2Si2	0.1640k	0.1508k
M_2Si_3	0.1220l	0.1097l
M_3Si_0	0.0778m	0.0697m
M_3Si_1	0.0500n	0.0427n
M_3Si_2	0.0225o	0.0165o
M_3Si_3	0.0055o	0.0025o
$LSD_{(0.05)}$	0.0202	0.0213
Level of significance	**	**
CV(%)	2.84	3.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly

** indicates 1% level of significance

MSE- Moringa Seed Extract
M_0: Control(0% MSE solution)
M_1; 3% MSE solution
M_2: 6% MSE solution
M_3:, 9% MSE solution

Si- Sodium Silicate
Si_0:Control(0 mg kg ^{1} soil)
Si_1: 100 mg kg^{-1} soil;
$Si_{2:}$ 200 mg kg^{-1} soil;
Si_3: 300 mg kg^{-1} soil

SUMMARY AND CONCLUSION

The pot experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2018 to February, 2019 to find out the effect of cadmium on potato and also to mitigate the effect by using moringa seed extract and silicon. Two factors were used in the experiment, *viz*. four doses of MSE - M_0 (control, 0% solution in 50 ml water kg^{-1} soil), M_1: 3% solution in 50 ml water kg^{-1} soil, M_2: 6% solution in 50 ml water kg^{-1} soil and M_3: 9% solution in 50 ml water kg^{-1} soil; and four doses of silicon as sodium silicate - Si_0: Control (0 $mgkg^{-1}$ soil), Si_1: 100 mg kg^{-1} soil, Si_2: 200 mg kg^{-1} soil and Si_3: 300 mg kg^{-1} soil. The experiment was laid out in a Randomized complete Block Design (RCBD) with four replications. Data on different growth, yield and quality contributing parameters were recorded.

Different levels of MSE had significant influence on growth, yield and yield contributing parameters. Considering the growth parameters, M_2 (10.25 days) required lowest days to emergence where highest required for M_0 (13.238 days) and M_3 required lowest days to maturity (81.5 days), where M_0 required highest (86.578 days). But the highest plant length (37.121 cm) was obtained from M_3 (9% MSE solution) and also the highest number of leaves $plant^{-1}$ (33.310) was observed from the same variety at 60 DAP, where the numbers were reduced thereafter. But the highest number of stem $plant^{-1}$ (9.9875), stem diameter (0.679 cm) and SPAD value (48.63 %) were obtained from the variety, M_3 (9 % MSE solution) at 75 DAP. Again, the lowest plant length (10.67 cm) , number of leaves $plant^{-1}$ (7.159) , the lowest number of stems $plant^{-1}$ (5.9506), stem diameter (0.248 cm) and SPAD value(33.12 %) were found from the variety, M_0 (0 % MSE solution) at 30DAP. In case of yield and yield contributing parameters, the highest number of tubers $plant^{-1}$ (7.7587), average wt. of individual tuber $plant^{-1}$ (44.438 g), weight of potato tubers $plant^{-1}$ (432.73 g) , marketable tubers (% by number) (63.152 %) and marketable tubers (% by weight) (75.486 %) were achieved from M_3 (9 % MSE solution). The lowest number tubers $plant^{-1}$ (3.7481), average wt. of individual tuber $plant^{-1}$ (37.125 g), weight of potato tubers plant^{-1} (119.21 g) , marketable tubers (% by number) (34.678 %) and marketable tubers (% by weight) (49.108 %) were achieved from M_0 (0 % MSE solution). In case of quality parameters, the highest stem dry matter content (13.496 %), tuber flesh dry matter content (21.951 %), peel dry matter content (22.669 %) were found in M_3 (9 % MSE solution). Whereas the lowest stem dry matter content (8.142 %), tuber flesh dry matter content (16.694 %), peel dry matter content (18.763 %) were found in M_0 (0 % MSE solution). But the highest specific gravity (1.0742) and total soluble solid (4.1231° Brix) were found in M_3 (9 % MSE solution), whereas the lowest specific gravity (1.0557) and total soluble solid (3.5988° Brix) were found in M_2 (6 % MSE solution).

Different levels of sodium silicate had also significant influence on growth, yield and yield contributing parameters. Considering the growth parameters, Si_2 (9.55 days) required lowest days to emergence where highest required for Si_0 (11.00 days) and Si_2 required lowest days to maturity (83.141days), where Si_0 required highest (84.539 days). But the highest plant length (27.756 cm) was obtained from Si_3 (300 mg sodium silicate kg^{-1} soil) and also the highest number of leaves plant^{-1} (28.943) was observed from the same variety at 60 DAP, where the numbers were reduced thereafter. But the highest number of stem plant^{-1} (9.4594), stem diameter (0.5684 cm) and SPAD value (42.09 %) were obtained from the variety, Si_3 (300 mg sodium silicate kg^{-1} soil) at 75 DAP. Again, the lowest plant length (17.544 cm) , number of leaves plant^{-1} (8.737) , the lowest number of stems plant^{-1} (6.5538), stem diameter (0.4627 cm) and SPAD value (38.26 %) were found from the variety, Si_0 (100 mg sodium silicate kg^{-1} soil) at 30DAP. In case of yield and yield contributing parameters, the highest number of tubers plant^{-1} (6.4919), average wt. of individual tuber plant^{-1} (42.563 g), weight of potato tubers plant^{-1} (299.92 g) , marketable tubers (% by number) (53.070 %) and marketable tubers (% by weight) (67.611 %) were achieved from Si_3 (300 mg sodium silicate kg^{-1} soil). The lowest number tubers plant^{-1} (5.5419), average wt. of individual tuber plant^{-1} (39.813 g), weight of potato tubers plant^{-1} (222.19 g) , marketable tubers (% by number) (46.930 %) and marketable tubers (% by weight) (58.100 %) were achieved from Si_0 (100 mg sodium silicate kg^{-1} soil). In case of quality parameters, the highest stem dry matter content (12.510 %), tuber flesh dry matter content (20.218 %), peel dry matter content (21.098 %) were found in Si_3 (300 mg sodium silicate kg^{-1} soil). Whereas the lowest stem dry matter content (10.591 %), tuber flesh dry matter content (18.959 %), peel dry matter content (20.304 %) were found in Si_0 (100 mg sodium silicate kg^{-1} soil). But the highest specific gravity (1.0678) was found in Si_3 (300 mg sodium silicate kg^{-1} soil) and lowest total soluble solid (3.6712° Brix) was found in Si_0 (100 mg sodium silicate kg^{-1} soil), whereas the lowest specific gravity (1.0641) was found in Si_3 (300 mg sodium silicate kg^{-1} soil) and highest total soluble solid (3.8388° Brix) were found in Si (6 % MSE solution).

Different levels of combinations of MSE and sodium silicate had also significant influence on growth, yield and yield contributing parameters. Considering the growth parameters, M_3Si_3 (10 days) required lowest days to emergence where highest required for M_0Si_0 (14.83 days) and M_3Si_3 required lowest days to maturity (81.907 days), where M_0Si_0 required highest (87.95 days). But the highest plant length (42.075 cm) was obtained from M_3Si_3 (9% MSE solution and 300 mg sodium silicate kg^{-1} soil) and also the highest number of leaves $plant^{-1}$ (34.99) was observed from the same variety at 60 DAP, where the numbers were reduced thereafter. But the highest number of stem $plant^{-1}$ (11.208), stem diameter (0.679 cm) and SPAD value (51.04 %) were obtained from the variety, M_3Si_3 (9 % MSE solution and 300 mg sodium silicate kg^{-1} soil) at 75 DAP. Again, the lowest plant length (8.3 cm) , number of leaves $plant^{-1}$ (6.4) , the lowest number of stems $plant^{-1}$ (3.9225), stem diameter (0.248 cm) and SPAD value (32.31 %) were found from the variety, M_0Si_0 (0 % MSE solution and 100 mg sodium silicate kg^{-1} soil) at 30DAP. In case of yield and yield contributing parameters, the highest number of tubers $plant^{-1}$ (8.1775), average wt. of individual tuber $plant^{-1}$ (45.25 g), weight of potato tubers $plant^{-1}$ (476.47 g) , marketable tubers (% by number) (64.96 %) and marketable tubers (% by weight) (78.393 %) were achieved from M_3Si_3. The lowest number tubers $plant^{-1}$ (3.0675), average wt. of individual tuber $plant^{-1}$ (35.5 g), weight of potato tubers $plant^{-1}$ (75.48 g) , marketable tubers (% by number) (32.438 %) and marketable tubers (% by weight) (39.69 %) were achieved from M_0Si_0 (100 mg sodium silicate kg^{-1} soil). In case of quality parameters, the highest stem dry matter content (14.263 %), tuber flesh dry matter content (22.225 %), peel dry matter content (22.788 %) were found in

M_3Si_3 (9 % MSE solution and 300 mg sodium silicate kg^{-1} soil). Whereas the lowest stem dry matter content (6.92 %), tuber flesh dry matter content (16.26 %), peel dry matter content (16.035 %) were found in M_0Si_0 (0 % MSE solution and 100 mg sodium silicate kg^{-1} soil). But the highest specific gravity (1.0762) was found in M_3Si_3 and lowest total soluble solid (3.665° Brix) was found in M_0Si_0, whereas the lowest specific gravity (1.0641) was found in M_3Si_3 (300 mg sodium silicate kg^{-1} soil) and highest total soluble solid (4.305° Brix) were found in M_0Si_0(6 % MSE solution).

RECOMMANDATION

1) The result of present study conclude that levels of potassium varied non-significantly for some growth parameter but significantly varied for different yield and quality of potato. From this experiment among the levels 9% solution of MSE performed better than the others levels considering yield and quality of potato although other performed also better in some growth parameters.

2) Among different levels of Sodium silicate levels, 300mg Sodium silicate kg^{-1} soil performed better than the other levels of Silicon.

3) Most of the yield and quality contributing parameters were found to be better using 9% MSE Solution along with 300mg Sodium silicate kg^{-1} soil. However in Bangladesh condition, industrialization becoming a burning question day by day. To cope up with it necessary steps should come out. This combination could be used as a useful remedy in order to mollify the toxic effect of Cd with sacrificing some amount of yield in heavily contaminated area up to 10 mg Cd kg^{-1} soil.

Considering the results of the present experiment, further studies in the following areas may be suggested:

1) For regional adaptability such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh where the soil are contaminated due to industrialization, specially near the agricultural lands.

2) Other doses of the treatments could be used for further study to specify the most useful combination.

3) Other sources of Moringa and Silicon could be used to find whether they are useful or not.

4) By using same or new doses of the treatments, this experiment could be repeated in different area with more or less Cd concentration.

5) Due to the lack of information about the main mechanism of the, more studies are needed to assay the uptake and transportation of nano-particles in plants. Further analysis at molecular level is needed.

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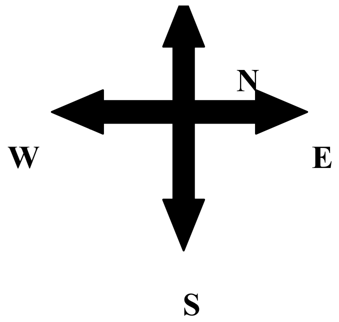
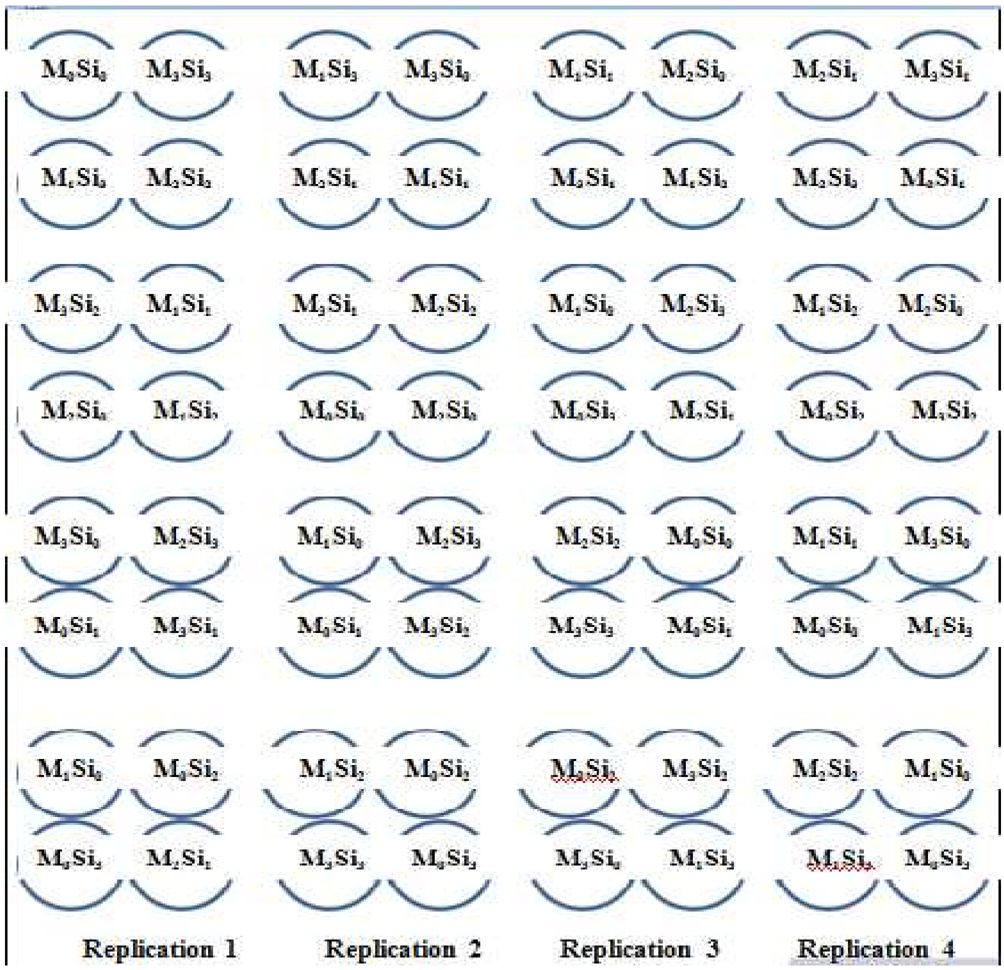
APPENDICES

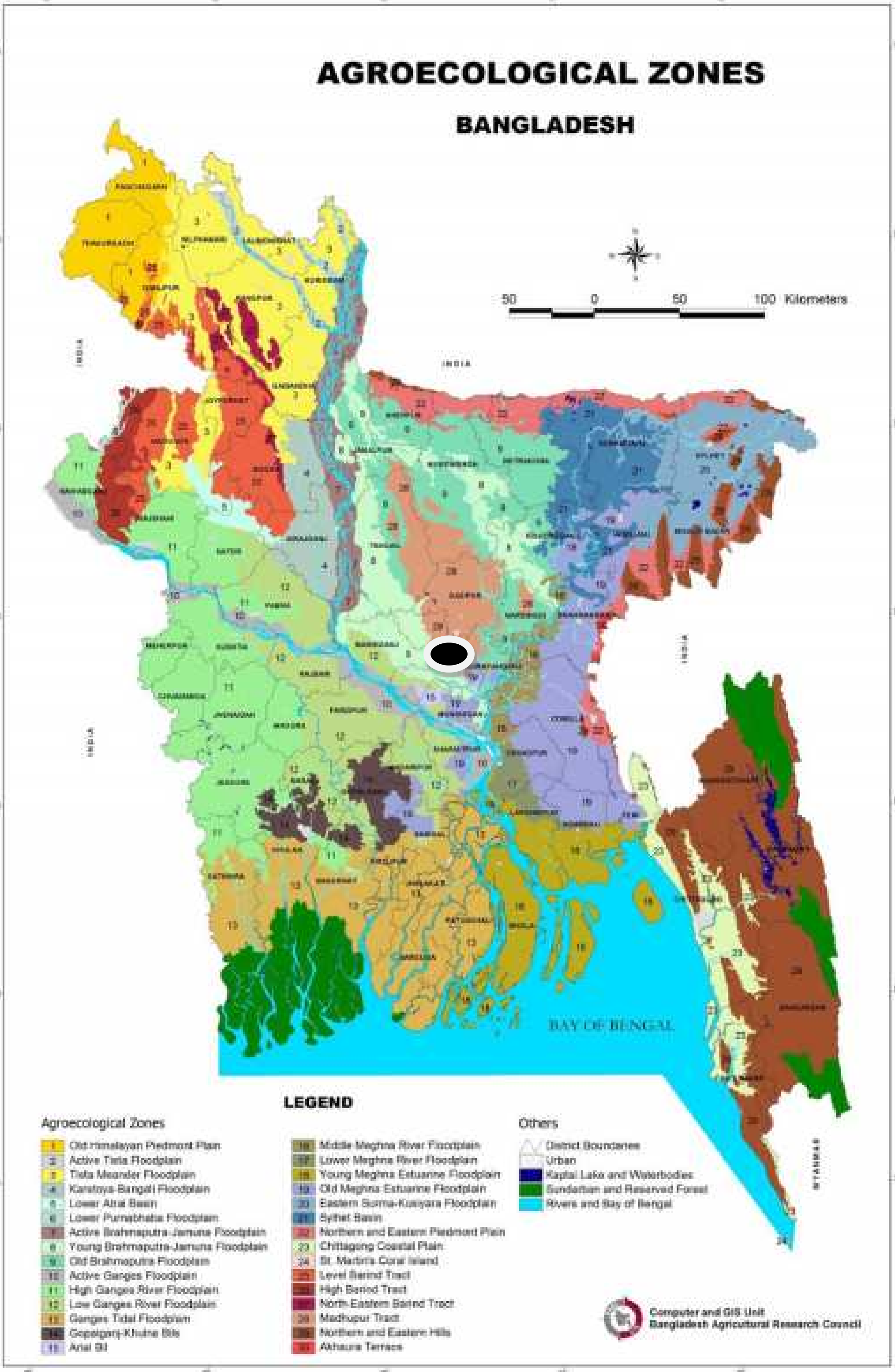
Appendix I Layout of the Experiment





M- Moringa Seed Extract levels	**Si-Sodium silicate levels**
M_0- 0% MSE solution in 50 ml water kg^{-1} soil	Si_0- 0 mgkg^{-1} soil
M_1- 3% MSE solution in 50 ml water kg^{-1} soil	Si_1- 100 mgkg^{-1} soil
M_2- 6% MSE solution in 50 ml water kg^{-1} soil	Si_2- 200 mgkg^{-1} soil
M_3- 9% MSE solution in 50 ml water kg^{-1} soil	Si_3- 300 mgkg^{-1} soil

Appendix II The Map of the experimental site



Appendix III Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November'18 to February'19

Month	Air temperature(^{0}C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximun	Minimum			
November'18	25.6	16.5	77	00	6.9
December'18	22.7	13.2	76	08	6.7
January'19	25.2	12.5	65	05	6.1
February'19	27.9	17.4	67	43	6.8

Source: Bangladesh Meteorological Department(Climate and weather division) Agargoan, Dhaka-1212

Appendix IV Soil characteristics of experimental field as per the Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental site, SAU, Dhaka
AEZ	Madhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgoan
Topography	Fairly leveled

B. Initial physical and chemical properties of the soil

Characteristics	Value
% Sand	26
% Silt	23
% Clay	31
Textural class	Sandy
pH	5.9
Cation Exchange Capacity(me 100^{-1} gm soil)	2.64
Organic matter(%)	1.15
Total N (%)	.03
Available P (ppm)	20.00
Exchangeable K(me 100^{-1} gm soil)	.10
Available S (ppm)	45

Appendix V Analysis of variance of the data on Days to emergence and Days to maturity at different DAP

Source of variance	DF	Mean Square value of Days to emergence	Mean Square value of Days to maturity
MSE	3	7.2010**	69.7370**
Silicate	3	26.0794*	7.4053*
MSE*Silicate	9	1.4438*	1.2847*
Error	48	.0.0245	1.0709
Total	63		

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix VI Analysis of variance of the data on Plant length at different DAP

Source of variance	DF	Mean Square value of Plant length at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
MSE	3	1576.71**	1486.12**	1431.96**	1366.67**	1258.96**
Silicate	3	118.44**	106.78**	111.71**	98.50**	92.99**
MSE*Silicate	9	7.23**	7.72**	8.78**	11.45**	15.32**
Error	48	0.07	0.10	0.15	0.16	0.35
Total	63					

** Significant at 0.01 level of probability

Appendix VII Analysis of variance of the data on No. of leaves plant^{-1} at different DAP

Source of variance	DF	Mean Square value of No. of leaves plant^{-1} at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
MSE	3	6993.07**	7841.42**	7213.45**	7191.00**	8784.98**
Silicate	3	429.06**	388.72**	454.11**	426.01**	491.61**
MSE*Silicate	9	6.54**	13.78**	8.53**	6.19**	3.70**
Error	48	0.73	0.20	0.97	0.37	0.57
Total	63					

** Significant at 0.01 level of probability

Appendix VIII Analysis of variance of the data on No. of stems plant[1] at different DAP

Source of variance	DF	Mean Square value of No. of stems hill^{-1} at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
MSE	3	22.4340**	27.4257**	31.2609**	31.2043**	41.2032**
Silicate	3	11.7126*	12.6093*	14.0115*	14.0563*	10.0418*
MSE*Silicate	9	1.9910^{NS}	1.7151^{NS}	1.6041^{NS}	1.5995^{NS}	1.8084^{NS}
Error	48	0.4065	0.2842	0.2929	0.2888	1.037
Total	63					

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

NS- Non-significant

Appendix IX Analysis of variance of the data on Diameter of stem at different DAP

Source of variance	DF	Mean Square value of Diameter of stem at				
		30 DAP	45 DAP	60 DAP	75 DAP	Harvest
MSE	3	0.21239**	0.15304**	0.12621**	0.12930**	0.12436**
Silicate	3	0.00854*	0.00287*	0.00141*	0.00146*	0.00152*
MSE*Silicate	9	0.01033*	0.00726*	0.00585*	0.00605*	0.00591*
Error	48	0.0029	0.00270	0.0023	0.00228	0.0022
Total	63					

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix X Analysis of variance of the data on the performance related to yield

Source of variance	DF	Mean Square value of the data on the performance related to yield				
		Stem dry matter content (%)	Tuber flesh dry matter content (%)	Tuber peel dry matter content (%)	Number of tuber plant^{-1}	Yiel d of tuber plant^{-1}
MSE	3	98.3660**	105.513**	82.2405**	49.3388**	53333.2**
Silicate	3	13.4771**	6.059**	7.0040**	2.8574**	21205.3**
MSE*Silicate	9	0.6698*	0.445*	0.6955*	0.2215*	7298.7*
Error	48	0.9169	0.4304	1.1364	0.0550	3367.35
Total	63					

** Significant at 0.01 level of probability   * Significant at 0.05 level of probability

Appendix XI Analysis of variance of the data on the performance related to yield

Source of variance	DF	Mean Square value of the data on the performance related to quality			
		Numberof marketable tubers	Number of non-marketable tubers	Weight of marketable tubers	Weight of non-marketable tubers
MSE	3	2431.43**	2431.43**	2073.42**	2073.42**
Silicate	3	97.28**	97.28**	313.83**	313.83**
MSE*Silicate	9	4.93	4.93	22.32**	22.32**
Error	48	1.401	1.401	4.45	4.45
Total	63				

** Significant at 0.01 level of probability

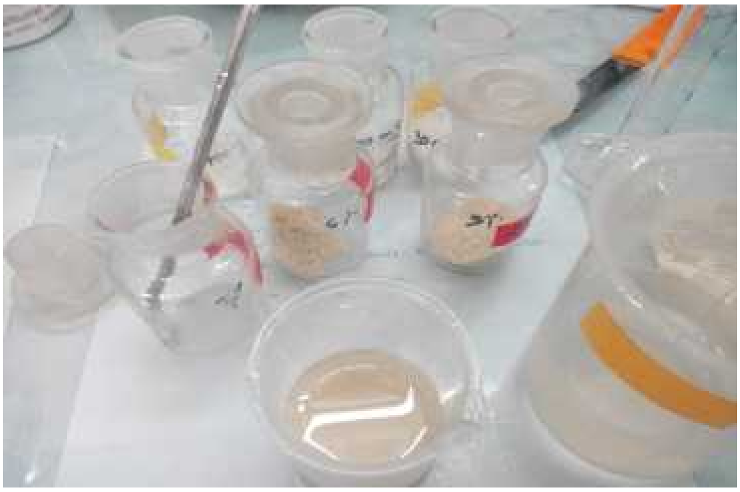
Appendix XII Analysis of variance of the data on the performance related to quality

Source of variance	DF	Mean Square value of the data on the performance related to quality				
		SPAD value of leaf (%)	Specific gravity of tuber(gm cm^{-3})	Total soluble sugar of tuber	Cd content of tuber flesh	Cd content of tuber peel
MSE	3	635.368**	0.004019**	1.20673	3.85882**	3.15773**
Silicate	3	43.536**	0.0001974*	0.08464*	0.59449*	0.31970*
MSE*Silicate	9	0.994	0.00002684**	0.02347	0.23848**	0.07839**
Error	48	.09644	0.000005813	0.03269	0.00020	0.00022
Total	63					

** Significant at 0.01 level of probability   * Significant at 0.05 level of probability

PLATES

Plate1. Overview of the experimental site



Plates 2. Preparation of Treatments

Plate 3. Application of Treatments

Plate 4. Plants showing Cd stress(M_0S_0, and M_1S_1,respectively)

Plate 5. Plant showing tolerance against Cd tress while treatments were applied(M_2S_2 and M_3S_3 respectively)

Plate 6. Potato tubers from two combination of same replication

Plate 7. Preparation for chemical analysis