GROWTH, YIELD AND QUALITY OF POTATO AS AFFECTED BY ARSENIC LEVELS

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH, YIELD AND QUALITY OF POTATO AS AFFECTED BY ARSENIC LEVELS"*** *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 (M.S.)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***MD. ANWAR HUSSAIN,*** *Registration. No.* ***06-01877****, 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Tuhin Suvra Roy)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
As	Arsenic
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Bd	Bangladesh
cm	Centi-meter
cm^2	Centi-meter squares
CV %	Percent Coefficient of Variance
DAP	Days After Planting
Dev.	Devlopment
Environ	Environmental
et al.	And others
Expt.	Experemental
FAO	Food and Agriculture Organization
g	Gram (s)
mg	Milligram
Sci.	Science
$hill^{-1}$	Per hill
i.e.	*id est* (L), that is
Res.	Research
j.	Journal
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter squares
M.S.	Master of Science
Na	Sodium
No.	Number
ppm	Parts per million
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
$t\ ha^{-1}$	Ton per hectare
UNDP	United Nations Development Programme
viz	Namely
%	Percentage

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ABSTRACT

A pot experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November 2011 to February 2012, to find out the effect of 5 different arsenic levels viz., As_0 (Control), As_1 (10 mg As kg^{-1} soil), As_2 (20 mg As kg^{-1} soil), As_3 (30 mg As kg^{-1} soil), As_4 (40 mg As kg^{-1} soil) on growth, yield and quality of four potato varieties viz., V_1 (Cardinal), V_2 (Diamant), V_3 (Asterix), V_4 (Granola). The application of As had significant effect on growth, yield and quality contributing parameters of potato irrespective of variety. Among the 5 As levels, 10 mg As kg^{-1} soil exhibited the positive performance for all growth and yield contributing characters except tuber number and quality contributing characters. Growth and yield contributing parameters increased up to application of 10 mg As kg^{-1} soil and thereafter decreased with increasing As levels. Marketable yield (>20 g) decreased with increasing As levels while As accumulation increased with increasing As levels irrespective of 4 potato varieties. Among 4 varieties, Diamant showed the best As tolerance and maximum growth whereas least in Granola. Out of 20 treatment combinations, Diamant cultivated with 10 mg As kg^{-1} soil performed the best results in terms of growth and yield. The maximum tuber yield $plant^{-1}$ (438.00 g) was obtained by Diamant with the application of 10 mg As kg^{-1} soil and the maximum marketable yield (93.14 %) was also produced by Diamant with control and the lowest from Granola (88.86 %) variety with 40 mg As kg^{-1} soil. The maximum As accumulation (0.22 mg kg^{-1}) was found in Granola at 40 mg As kg^{-1} soil whereas the minimum (0.05 mg kg^{-1}) was in Diamant with 10 mg As kg^{-1} soil except control, which is less than critical level (0.15 mg kg^{-1}) for human body. On the basis of yield and As tolerance the variety Diamant was superior than those of other varieties.

CHAPTER I
INTRODUCTION

Arsenic (As) is one of the toxic environmental pollutants which has recently attract attention because of its chronic and epidemic effects on human health through widespread water and crop contamination due to the natural release of this toxic element from aquifer rocks in Bangladesh (Smith *et al*., 2000; Ahmed, 2000; Fazal *et al*., 2001; Hopenhayn, 2006), West Bengal, India (Chakraborti and Das, 1997; Banerjee, 2000). The toxic metalloid As is widely distributed in nature, e.g., in soil, water, air, plant, animal and human body. Generally, the background of As levels in top soils is low (Kabata-Pendias, 1992).

Arsenic contamination of surface and groundwater occurs worldwide and has become a sociopolitical issue in several parts of the globe. Around 110 million of those people live in 10 countries in South and South-east Asia: Bangladesh, Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan, Taiwan and Vietnam. It has recently been recognized that As-contaminated groundwater used for irrigation may pose an equally serious health hazard to people eating food from the irrigated crops (Williams *et al*., 2006), and that As accumulating in irrigated soils poses a serious threat to sustainable agriculture in affected areas (Heikens, 2006).

Arsenic contamination of groundwater is a serious problem in Bangladesh. Naturally-occurring As contaminated water was first detected in Bangladesh in 1993 (Khan *et al*., 1997). It was believed that As contamination is not caused by tube wells or by irrigation or application of fertilizers. But now-a-days it suggests that widespread use of groundwater for irrigation is another route of As which enter the food chain and indirectly affect human health. Duxbury *et al*. (2003) mentioned the presence of arsenic in food chain.

It is highly hazardous to human and animal health. As small as 0.1 g of arsenic trioxide (As_2O_3) can prove lethal to human (Jarup, 1992). Arsenic is the causal factor of several physiological disorders in human namely edema, skin lesions, hyperkeratosis, skin cancer and even death (Das *et al*., 1996; Sanyal and Naser, 2002).

Bangladesh is predominantly an agricultural country. The people of Bangladesh are not only drink the arsenic contaminated groundwater but also irrigate their crops. About 86% of the total groundwater withdrawn is utilized in the agricultural sector (Imamul Huq *et al*., 2005a). If water is polluted, it may be dangerous for plants, animals as well as for human being. Irrigation is principally performed in dry season for Rabi crop cultivation. Most groundwater used for irrigation in Bangladesh is contaminated with arsenic (Khan *et al*., 1998). Long-term irrigation with arsenic contaminated groundwater is likely to increase its concentration in crops (Ullah, 1998; Imamul Huq *et al*., 2003).

The agricultural soil of As non-contaminated areas of Bangladesh contain 4.0 to 8.0 mg of As kg^{-1} while that irrigated with As contaminated groundwater, contain up to 83 mg of As kg^{-1} (Ullah, 1998). The maximum acceptable concentration of arsenic in agricultural soil is 20 mg kg^{-1} (Kabata-Pendias and Pendias, 1992). The use of As contaminated irrigation water create hazard both in soil environment and in crop quality. About 20% loss of crop (cereal) production happened due to high concentration (20 mg kg^{-1}) of As in plant body (Davis *et al*., 1998). High As irrigated water and soil appears to result in higher concentration of As in root, stem and leaf of rice plants (Abedin *et al.*, 2002b).

Arsenic accumulation in the plant parts depends on many factors such as plant species, soil type, nutrient supply and p^H (Tu and Ma, 2003), among them plant species is an important factor. An increase of As concentrations in cultivated medium lead to an increase in As levels in the edible parts of vegetables (Farid *et al*., 2003; Imamul Huq *et al*., 2005; Shamsuddoha *et al*., 2005; Shaibur *et al*., 2009a). Arsenic content of different vegetables grown with As containing irrigation water were found in the descending order of: Amaranth (0.093-2.791

mg kg^{-1v}), Indian spinach (0.096-0.387 mg kg^{-1}), chilli (0.112 mg kg^{-1}), bitter gourd (0.091 mg kg^{-1}), cabbage (0.031-0.042 mg kg^{-1}), brinjal (0.042-0.063 mg kg^{-1}), okra (0.034-0.046 mg kg^{-1}), tomato (0.016-0.049 mg kg^{-1}), cauliflower (0.011 mg kg^{-1}) (Farid *et. al* 2003).

Potato (*Solanum tuberosum* L.) is one of the major food crops of the world. In Bangladesh, it ranks second after rice in production (FAOSTAT, 2011). The total area under potato crop, per acre yield and total production in Bangladesh are 1137000 acres, 7321 kg per acres and 8326000 metric tons, respectively (BBS, 2011).The total production is increasing day by day as such consumption also rapidly increasing in Bangladesh (BBS, 2011). Potato varieties cultivated during the winter in all the districts of Bangladesh.

Larsen *et al.* (1992) found that leafy plants accumulated arsenic by atmospheric deposition, whereas, tuberous plant such as potatoes and carrots accumulated arsenic by both root uptake and atmospheric deposition. Potato grown in As-containing irrigation showed (0.013-0.390 mg kg^{-1}) As accumulation in plant as reported by Farid *et al.*, 2003. People of Arsenic affected areas are consuming contaminated potatoes which may create serious problem for human health.

Very limited work has been done on the effects of using As contaminated water on potato production and toxicity in potatoes and its impact on sustainable agriculture. In this point of view current research was conducted with following objectes -

i. To study the effect of As on the growth, yield and quality of potatoes.
ii. To find out As tolerance in potato varieties.

CHAPTER II

REVIEW OF LITERATURE

2.1 Arsenic effect

Rahaman *et al.* (2013) set an experiment on five blocks under Malda district of West Bengal, India, showed that the arsenic concentration in groundwater (0.41–1.01 mg L^{-1}) was higher than the permissible limit for drinking water (0.01 mg L^{-1}) (WHO) and FAO (Food and Agriculture Organization) permissible limit for irrigation water (0.10 mg L^{-1}). The highest mean arsenic concentration was found in potato (0.456 mg/kg), followed by rice grain (0.429 mg kg^{-1}). The total mean arsenic content (milligrams per kg dry weight) in cereals ranged from 0.121 to 0.429 mg kg^{-1}, in pulses and oilseeds ranged from 0.076 to 0.168 mg kg^{-1}, in tuber crops ranged from 0.243 to 0.456 mg kg^{-1}, in spices ranged from 0.031 to 0.175 mg kg^{-1}, in fruits ranged from 0.021 to 0.145 mg kg^{-1} and in vegetables ranged from0.032 to 0.411 mg kg^{-1}, respectively. Hence, arsenic accumulation in cereals, pulses, oilseed, vegetables, spices, cole crop and fruits crop might not be safe in future without any sustainable mitigation strategies to avert the potential arsenic toxicity on the human health in the contaminated areas.

Santra *et al.* (2013) taht dnuof tuberous vegetables accumulated higher amount of As than leafy vegetables and leafy vegetables followed by fruity vegetable. The highest As accumulation was observed in potato, brinjal, arum, amaranth, radish, lady's finger, cauliflower whereas lower level of As accumulation was observed in beans, green chilli, tomato, bitter guard, lemon, turmeric. The major oil seed of this region is mustard and was found to accumulate As in the range 0.339-0.373 mg kg^{-1}. In pulses group, pea showed the highest As content of 1.30 mg kg^{-1} whereas moong (Mung bean) found the lowest value (0.314 mg kg^{-1}). The As accumulation was found to be more in Boro rice than in Aman, while high yielding rice varieties were found to accumulate more As than local.

Sultana *et al.* (2012) conducted a pot experiment to study the effects of As containing irrigation water on growth, yield and nutrient accumulation of *Vigna radiata* (mung bean) in two different soils – one is non calcareous and non saline (Sara soil series) and the other is calcareous and slightly saline (Barisal soil series). The levels of arsenic used in irrigation water were 0, 1, 2, 5 and 10 mg L^{-1}. Root and shoot growth parameters, yield and nutrient accumulation were studied to assess the effect of arsenic. All the growth parameters responded better at 2 mg L^{-1} concentration in both soils. The parameters of growth and yield studied, almost all showed to be drastically affected by 10 ppm treatment. Accumulation of all the studied nutrients in shoot decreased while accumulation of iron increased with increasing arsenic concentrations.

Norton *et al.* (2013) carried out a field and market basket study (~1300 samples) of locally grown fruits and vegetables from historically mined regions of southwest (SW) England (Cornwall and Devon), and as reference, a market basket study of similarly locally grown produce from the northeast (NE) of Scotland (Aberdeenshire) was conducted to determine the concentration of total and inorganic arsenic present in produce from these two geogenically different areas of the U.K. On average 98.5% of the total arsenic found was present in the inorganic form. For both the market basket and the field survey, the highest total arsenic was present in open leaf structure produce (i.e., kale, chard, lettuce, greens, and spinach) being most likely to soil/dust contamination of the open leaf structure. The concentration of total arsenic in potatoes, swedes, and carrots was lower in peeled produce compared to unpeeled produce. For baked potatoes, the concentration of total arsenic in the skin was higher compared to the total arsenic concentration of the potato flesh.

Rajib *et al.* (2012) conducted a field experiment to evaluate the varietal tolerance and accumulation of As by different potato cultivars at village Nonaghata in Nadia district of West Bengal during winter season of 2008-09 and 2009-10. As content in the irrigation water was 0.094 to 0.108 mg L^{-1}. As accumulation of different plant parts was in the following sequence: root >

stem > leaf > tuber, irrespective of all cultivars. After harvesting, the least As loading was observed in cultivar Kufri Jyoti (0.05 mg kg^{-1}) which also showed the highest productivity (32.32 t ha^{-1}). Cultivar Kufri Chandramukhi and locally grown variety *Lal alu* accumulated a lesser amount of As and had also a higher yield compared with the other entries.

Talukdar, D. (2011) was carried out an experiment on effect of As-induced toxicity on morphological traits of *Trigonella foenum-graecum* L. and *Lathyrus sativus* L. during germination and early seedling growth. He used five different concentrations (0, 10, 20, 30 and 40 mg L^{-1}) of As on 11 different parameters of two important leguminous crops during germination and early seedling growth stage. Mean value of germination percentage, germination index and relative germination rate decreased with concomitant increase in As-induced injury level in increasing concentration of As in both plants and the effect was significant at 30 and 40 mg L^{-1} treatments.

Sushant and Ghosh (2010) carried out a pot experiment was designed and conducted to investigate the effect of As on photosynthetic pigments, Chlorophyll a and Chlorophyll b, growth behavior, and its accumulation in the tissues of different parts of onion plants (*Allium cepa*). Test plants were subjected to pot experiment under natural conditions. Four pots were prepared to grow onion plants, irrigated with equal volume of different As solution ($NaAs_3$), 0.00 mg L^{-1}, 0.200mg L^{-1}, 0.600mg L^{-1}, and 0.800mg L^{-1} concentration with one pot for control respectively, throughout the experiments. Both chlorophyll-a and chlorophyll-b contents in onion leaf increased significantly with the increase of water As concentrations. The highest chlorophyll a (0.004847 g^{-1}) and chlorophyll b (0.006528 g^{-1}) contents were estimated in the onion leaf irrigated with 0.800mg L^{-1} of As whereas, in control plant it was lowest (chl-a 0.002363 g^{-1} and chl-b 0.004092 g^{-1}). A high positive correlation was observed between water As (R^2= 0.897 and 0.963) & soil As (R^2= 0.926 and 0.919) with chlorophyll a and chlorophyll b respectively. High positive correlation was also observed even for onion growth verses soil As and water As (R^2=0.994 and 0.968) and water As with leaf biomass (R^2=0.973) respectively. However, no As accumulation was detected in the tissues of different parts of the onion plants suggesting that, As ($NaAs_3$) influenced the biochemistry of photosynthesis which ultimately resulted in the increase of onion growth and yield.

Karim *et al.* (2008) An investigation of various heavy metals including the arsenic (As) poisoning in soils and vegetables in five upazillas under Feni district of Bangladesh was performed by Bangladesh Atomic Energy Research Establishment (BAERE), Savar, Dhaka. A total of 30 samples (15 surface soils and 15 foodstuffs) were studied in five Upazillas of Feni district taking three samples of each kind from each upazilla. Samples were assessed and screened for As, Br, U, Th, Cr, Sc, Fe, Zn and Co in soils and As, Br, Na, K, Cr, Sc, Fe, Zn and Co in vegetables (i.e; eddoe, taro, green papaya, plantain, potato, callaloo, bottle ground and carambola). Among all contaminants, only As, Zn and Cr for both samples were focused because of their higher values compared with the local as well as the world typical values. The present results revealed that the mean levels of As in Parsuram, Feni Sadar and Pulgazi upazillas are higher than the world typical value of 2 mg/kg. For the case of vegetables, the mean concentration of As is found only in Eddoe (5.33 ppm) and Taro (1.46 ppm) collected from Sonagazi and Feni Sadar upazilla; which are higher than the values in Samta (0.1 ppm for eddoe and 0.44 ppm for taro) under Jessore district of Bangladesh. The mean concentrations of Zn and Cr in all kinds of vegetables are higher compared with the existing local values as well as the world typical values. The mean estimated daily dietary intake of As, Zn and Cr from vegetables are found to be 0.105, 12.47 and 3.53 mg respectively, which are higher than the recommended values of some countries. The consumption of toxic metals in vegetables is a risk for public health in the studied area.

Juzl and Stefl (2002) conducted an experiment to find out the effect of leaf area index on potatoes yield in soils contaminated by some heavy metals viz. cadmium (Cd), arsenic (As) and beryllium (Br). Their experiment was performed at sequential terms of sampling from two potato varieties with different duration of growing season. From a growers view the phytotoxic influence on development of assimilatory apparatus and yields during the growth of a very-early variety Rosara and a medium-early Korela were evaluated. These varieties were grown under field conditions in soils contaminated by graded levels of Cd, As and Br. The yields of tubers were negatively influenced by graded levels of heavy metals on both chosen varieties. The highest phytotoxic influence was recorded of As and the lowest of Cd. Significant influence of As and Br on size of leaf area index in the highest applied variants was found. The influence of experimental years on tuber yields was also statistically significant.

Abedin *et al.* (2002a) carried out an experiment on long-term use of As contaminated ground for irrigation in Bangladesh for rice seed germination and seedling establishment. Percent germination over control decreased significantly with increasing concentrations of arsenite and arsenate. Arsenite was found to be more toxic than arsenate for rice seed germination. There were varietal differences among the test varieties in response to arsenite and arsenate exposure. The performance of the dry season variety Purbachi was the best among the varieties. Germination of Purbachi was not inhibited at all up to 4 mg L^{-1} arsenite and 8 mg L^{-1} arsenate treatment. Root tolerance index (RTI) and relative shoot height (RSH) for rice seedlings decreased with increasing concentrations of arsenite and arsenate. Reduction of RTI caused by arsenate was higher than that of arsenite. In general, dry season varieties have more tolerance to arsenite or arsenate than the wet season varieties.

Abedin *et al.* (2002b) observed on long-term use of As contaminated groundwater to irrigate crops, especially paddy rice (*Oryza sativa* L.). A greenhouse pot experiment was conducted to evaluate the impact of As-contaminated irrigation water on the growth and uptake of As into rice grain, husk, straw and root. There were altogether 10 treatments which were a combination of five arsenate irrigation water concentrations (0–8 mg As L^{-1})

and two soil phosphate amendments. Use of arsenate containing irrigation water reduced plant height, decreased rice yield and affected development of root growth. As concentrations in all plant parts increased with increasing arsenate concentration in irrigation water. However, As concentration in rice grain did not exceed the maximum permissible limit of 1.0 mg As kg^{-1}. As accumulation in rice straw at very high levels indicates that feeding cattle with such contaminated straw could be a direct threat for their health and also, indirectly, to human health.

Ducsay (2000), conducted an experiment in laboratory conditions to investigate the impacts of upward doses of As, cadmium (Cd) and lead (Pb) on quality of cultivated biomass wheat (*Triticum aestivum* L.) during 21 days and production of chlorophyll a and chlorophyll b. The most expressive decrease of growth crops were found in As, Cd and Pb. The increase of their concentrations in soil caused increasing of their concentration in biomass.

Carbonell-Barrachina *et al.* (1998) reports on the uptake, potential bioavailability and phytotoxocity of As to an important wetland plant species growing in the vicinity of produced water discharge. The effects caused by As chemical form and concentration on growth, tissue concentrations and distribution of As and nutrient elements were studied in Spartina patens, growing in hydroponic conditions. The experiment was conducted with four As chemical forms [arsenite, As(III); arsenate, As(V); monomethyl arsonic acid, MMAA; and dimethyl arsinic acid, DMAA] and four As concentrations (0, 0.2, 0.8, and 2.0 mg As. L^{-1}). As phytoavailability and phytotoxicity were primarily determined by the As chemical form present in the nutrient solution. DMAA was the most phytotoxic species to this marsh grass. As(V) and MMAA significantly increased total dry biomass production at low As rates of application. The As concentrations in root and shoot were significantly increased by increasing As application rates (all four species) to the rooting medium. As chemical form and concentration significantly affected macro and micro-nutrient concentrations in plant tissue. Plants treated with As(V) had an improved growth compared to control plants; this seemed to be associated to an increase in plant P concentrations. Organic arsenicals caused the highest Na root concentrations and simultaneously the lowest plant K levels (antagonism K-Na). A significant decreased in leaf Ca concentrations was found in practically all As treatments. Organic arsenicals significantly decreased the concentrations of root Cu, Fe, and Mn and shoot B and Cu. The high phytotoxicity of the DMAA treatments appears to be related to the significant reductions in the concentrations of several essential macronutrients P, K, Ca, and Mg and micronutrients B, Cu, Fe, and Mn.

Carbonell-Barrachina *et al.* (1997) set an experiment on As (As) absorption by tomato (*Lycopersicum esculentum* Mill) and bean (*Phaseolus vulgaris* L.) as affected by arsenite concentration in nutrient solution. The processes of As uptake and accumulation among roots, stems, leaves, and fruit were studied. Tomato and bean plants were grown in nutrient solution containing four levels of arsenite: 0, 2, 5, and 10 mg As L^{-1}. Arsenite was phytotoxic to both plant species; tomato plants, however, were more tolerant to As pollution than bean plants. Bean plants exhibited symptoms of As toxicity, and plants treated with 10 mg As L^{-1} were dead after 36 days of treatment. In tomato, As exposure resulted in a significant reduction in dry biomass production but tissue chlorosis or necrosis were not observed. The strategy developed by tomato plants to tolerate As was avoidance; limiting As transport to shoots and increasing As accumulation in the root system. As in tomato root tissue seemed to be so effectively compartmentalized that its impact in plant growth and metabolism was minimal. However, in bean plants upon uptake, As was readily transported to shoots and accumulated to high concentrations in leaf tissue. The observed differential absorption and translocation of arsenite or its metabolized species by tomato and bean plants were probably responsible for the different plant tolerance to As pollution.

Carbonell-Barrachinaa *et al.* (1995) conducted an experiment to find out the response of tomato (*Lycopersicum esculentum*) plants to different levels of As in nutrient solution was investigated the processes of uptake, distribution and accumulation of As and the effect of arsenite on yield and plant growth (plant height, diameter of stem, stem and root length, fresh and dry weight of root, stems, leaves, and fruit). Their experiment was performed at three levels of As: 2, 5 and 10 mg L^{-1} [added as sodium arsenite ($NaAsO_2$)] in a nutrient solution, together with the corresponding control plants. As uptake depended on the As concentration in solution and As content in the roots increased as the time of treatment increased. The most important finding was the high toxicity of arsenite to roots. The concentration in stems, leaves, and fruit was correlated with the As level in the nutrient solution. Although the As level of 10 mg L^{-1} damaged the root membranes, resulting in a significant decrease in the upward transport of As. As exposure resulted in a drastic decrease in plant growth parameters (e.g., maximum decrease of 76.8% in leaf fresh weight) and in tomato fruit yield (maximum reduction of 79.6%).

Onken and Hossner (1995) set an experiment to study on determined the species and concentrations of As present in soil solution of flooded soils and correlated them to As concentration, P concentration, and growth rate of plants grown in treated soils. Rice (*Oryza sativa* L.) was grown in two soils treated with 0, 5, 15, 25, 35, and 45 mg As kg^{-1} soil added as either Na-arsenate or Na-arsenite. Soil solution samples and plant samples were collected over a period of 60 d. The As concentration of rice plants best correlated to the mean soil solution arsenate concentration in a Beaumont clay (fine, montmorillonitic, thermic Entic Pelludert) and to the mean soil solution arsenite concentration in a Midland silt loam (fine, montmorillonitic, thermic Typic Ochraqualf). In both soils, plant P concentration was best correlated to the amount of As added to the soil rather than any soil solution As concentration. Plant weight was best correlated to the mean soil solution arsenate concentration in both soils. The rate of As uptake by plants increased as the rate of plant growth increased. Plants grown in soils treated with As had higher rates of As uptake for similar rates of growth when compared with plants in untreated soils. However, growth per unit of As uptake was higher for plants in untreated soils than plants in As treated soils.

Jacobs *et al.* (1970) conducted an experiment to find out the As residue toxicity to vegetable crops grown on Plainfield sand. In a field study, sodium arsenite, was applied to a Plainfield sand at rates ranging from 45 to 720 kg As ha^{-1}. The plots were planted to potatoes in 1967; peas, snap beans, and sweet corn in 1968; and to peas in 1969. Yields of potatoes were greater than check at the 45 and 90 kg As ha^{-1} rates, but decreased to 79 and 24% of check yield at the high As rates. Snap bean and sweet corn yields also decreased with increasing As, and no growth was obtained on the high As plots. The As content of above-ground portions of potatoes varied widely, and bore no relationship to As treatment. Evidence of As contamination by windblown As-treated soil was obtained. As was below detectable limits in edible portions of peas and sweet corn, but up to 0.5 ppm of As accumulated in potato tubers and up to 84 ppm in potato peelings. The finding that yield reductions and As contamination of vegetable crops will occur indicates that use of As as a potato vine defoliant on sandy soils should be discouraged.

2.2 Varietal effect

Islam *et al.* (2009) conducted an experiment with three potato varieties to observe their performance on yield under different soil moisture levels. The highest plant height (50.75 cm) was found in Cardinal which was similar to Diamant (48.88 cm). The lowest plant height was observed in Granola (38.50 cm). Among the varieties, Cardinal gave the highest yield (25.20 t/ha) and Granola gave the lowest yield (17.22 t/ha).

Hossain *et al.* (2003) observed that the yield contributing characters of the varieties differed significantly. Highest yield (27.31 t ha^{-1}) was obtained from the variety Akira and it was identical to Jacrla (26.30 t ha^{-1}) and these two varieties out yielded the check variety Diamant (22.81 t ha^{-1}). The varieties carlita, Baraka. Jaerla, Bintje, Midas, Ultra, Akira, Dura, Granola, Futuri and Diamant yielded more than 20.0 t ha^{-1}. Most of the varieties perhaps did not able to show their full yield potentially due to the new environment of their first generation in Bangladesh.

Anonymous (1988) conducted a field trial with 69 exotic varieties of potato and noted that Ajax, Bartina, Cardinal, Corine, Diamant. Farnosa. Favorita, Frisia. Mondial and Morene gave yields above 25 t ha^{-1} in the second generation. In the third generation only two varieties namely, Allard and Cardinal gave yields above 20 t ha^{-1}.

Field performance of potato varieties generations such as first, second and third were conducted at different locations of MC (Anonymous, 1987a). In the first generation, the highest yield was given by Claudia (29.7 t ha^{-1}a) closely followed by Mondial (29.6 t ha^{-1}), Cardinal (28.9 t ha^{-1}), Allard (28.6 t ha^{-1}) and Diamant (28.5 t ha^{-1}). in the second generation, the highest yielder was Diamant (22.0 t ha^{-1}) closely followed by Elvira (21.8 t ha^{-1}), Cardinal (21.5 t ha^{-1}), Allard (20.7 t ha^{-1}) and Cleopatra (20.7 t ha^{-1}). Highest yield was obtained from Kondor (18.7 t ha^{-1}) in the third generation followed by Cardinal and Diamant.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field Laboratory, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2011 to February, 2012.

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 "The Modhupur Tract", AEZ-28 (Anon., 1988a). 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., 1988b).

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.

3.2 Details of the Experiment

3.2.1 Treatments

Two sets of treatments included in the experiment were as follows:

A. Variety 4:

1. V_1 – BARI Alu-8 (Cardinal)
2. V_2 – BARI Alu-7 (Diamant)
3. V_3 – BARI Alu-25 (Asterix)
4. V_4 – BARI Alu-13 (Granola)

B. Arsenic levels: 5

1. As_0 – 0 mg As kg^{-1} soil
2. As_1 – 10 mg As kg^{-1} soil
3. As_2 – 20 mg As kg^{-1} soil
4. As_3 – 30 mg As kg^{-1} soil
5. As_4 – 40 mg As kg^{-1} soil

Treatment combinations were as:

V_1As_0, V_1As_1, V_1As_2, V_1As_3, V_1As_4, V_2As_0, V_2As_1, V_2As_2, V_2As_3, V_2As_4, V_3As_0, V_3As_1, V_3As_2, V_3As_3, V_3As_4, V_4As_0, V_4As_1, V_4As_2, V_4As_3, V_4As_4.

3.2.2 Experimental design

Experiment was provoked in Randomized Complete Block Design (RCBD) with three replications thus comprised 60 baskets. The size of each basket was 25 cm (10 inches) in diameter and 30 cm (12 inches) in height. The distances between basket to basket and replication to replication were 25 cm and 1.0 m, respectively. The layout of the experiment has been shown in Appendix I.

3.3 Crop/Planting material

The planting materials comprised the foundation seed tubers of four modern varieties of potato. The varieties were Cardinal (V_1), Diamant (V_2), Asterix (V_3) and Granola (V_4).

3.4 Crop management

3.4.1 Seed collection

All variety of seed potato (foundation seed) was collected from, BARI sub-station, Debigonj, Panchagarh District., Bangladesh. Individual weight of seed potato was 60-70 g.

3.4.2 Seed preparation

Collected seed tubers were kept in room temperature to facilitate sprouting. Finally 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 use to control leaching loss of arsenic by irrigation water. Baskets were filled up 7 days before planting on 3rd November 2011.

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 sulphate and boric acid.

Fertilizers	Dose (kg ha^{-1})	Dose (g 10 kg soil^{-1})
Urea	250	1.25
TSP	150	0.75
MP	250	1.25
Gypsum	120	0.6
Zinc Sulphate	10	0.05
Boric Acid	10	0.05

Source: Mandal *et al.*, 2011

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 Arsenic treatment

For the Arsenic treatment of soil, sodium meta arsenate (Na_2HAsO_4. 7 H_2O) was used as the source of Arsenic. Arsenic application was done by adding 0 mg kg^{-1} soil, 10 mg kg^{-1} soil, 20 mg kg^{-1} soil, 30 mg kg^{-1} soil and 40 mg kg^{-1} soil Arsenate into soil of baskets according to treatment.

3.4.6 Tagging

Tagging was done by application of Arsenic on 7th November 2011 using card.

3.4.7 Planting of seed tuber

Seed tubers were foundation seed and that's why seed treating was not required. The well sprouted healthy and uniform sized (60-70 g) potato tubers were planted according to treatment 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 10th November 2011.

3.4.8 Intercultural operations

3.4.8.1 Weeding

Weeding was performed in all baskets as and when required to keep plant free from weeds.

3.4.8.2 Watering

Frequency of watering depended upon soil moisture status by observing visually. However, avoided water logging, as it is detrimental to plants.

3.4.8.3 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.

3.4.8.4 Disease and pest management

Experimental potatoes were foundation seed and environmental condition was not favorable for late blight of potato. Only one of the plants was affected by early blight which did not hampered on plant growth.

3.4.8.5 Haulm cutting

Haulm cutting was done at 8th 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.

3.4.8.5 Harvesting of potatoes

Harvesting of potato was done at 15th 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 from which yield of tuber converted to t ha^{-1}. Harvesting was done manually by hand.

3.4.9 Recording of data

Experimental data were determined from 30 days of growth duration and continued until harvest. Dry weights of different plant parts were collected after harvesting. The followings data were determined during the experiment.

A. Crop growth characters
   i. Days to emergence
   ii. Plant height (cm)
   iii. Number of leaves plant^{-1}
   iv. Number of stems hill^{-1}
   v. Leaf area plant^{-1} (cm^2)
   vi. Stem diameter (cm)
   vii. Stem dry matter content (%)

B. Yield and yield components
   viii. Tuber flesh dry matter content (%)
   ix. Tuber peel dry matter content (%)
   x. Number of tubers hill^{-1}
   xi. Yield of tuber plant^{-1} (g)

C. Quality characters
   xii. Grade of tubers (on the basis of size in diameter)
   xiii. Grade of tubers (on the basis of weight)
   xiv. Arsenic content of tuber peel
   xv. Arsenic content of tuber flesh

3.4.10 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 from the date of potato tuber sowing.

ii. Plant height (cm)

Plant height was measured at 30, 45, 60, 75 and 90 DAP. The height of each plant of each basket was measured in cm by using meter scale and mean was calculated.

iii. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at 30, 45, 60, 75 and 90 DAP. Leaves number plant^{-1} were recorded by counting all leaves from each plant of each basket and mean was calculated.

iv. Number of stems hill^{-1}

Number of stems hill^{-1} was counted at 30, 45, 60, 75 and 90 DAP. Stem numbers hill^{-1} were recorded by counting all stem from each basket.

v. Leaf area plant^{-1} (cm^2)

Leaf area plant^{-1} was measured by non-destructive method using CL-202 Leaf Area Meter (USA). Mature leaf (from 4th node) were measured all time and expressed in cm^2. Three mature plant of each pot were measured and then average it after that mean was calculated.

vi. Stem diameter (cm)

Stem diameter was measured at 30, 45, 60, 75 and 90 DAP. The stem diameter of each plant of each basket was measured in cm by using Slide Calipers and mean was calculated.

vii. Stem dry matter content (%)

Fresh weight of haulm was taken first. Then the samples of stem were oven dried until a constant level from which the dry matter percentage of above ground harvest was calculated with the following formula:

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

B. Yield and yield components

viii. Tuber dry matter content (%)

The samples of tuber were collected from each treatment. After peel off the tubers the sample was oven dried until a constant level from which the weights of tuber dry matter content % were recorded.

ix. Tuber peel dry matter content (%)

The peel of tubers of each sample were collected from each treatment and oven dried until a constant level from which the weights of tuber dry matter content % were recorded.

x. Number of tubers hill^{-1}

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

xi. Yield of tuber plant^{-1} (g)

Tubers of each basket were collected separately from which yield of tuber hill^{-1} was recorded in gram.

C. Quality Characters

Xii. Grading of tuber

Harvested tubers were graded into two forms

a. On the basis of size in diameter of tuber as affected by As contamination:

On the basis of size in diameter tubers have been graded into A (>55mm), B (45-55mm), C (28-45mm) and D (<28mm). A special type of frame (potato riddle) was used to grading of tuber.

b. On the basis of weight

On the basis of weight tubers have been graded into marketable tuber (>20g) and non-marketable tuber (<20g).

xiii. Preparation for chemical analysis

Potatoes were harvested and packed with labeled polythene bag. These labeled packed tubers were immediately sent to 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 (HG-AAS) following USEPA method 1632.

3.4.11 Statistical Analysis

Collected data were statistically analyzed using MSTAT-C computer package programme. Mean for every treatments were calculated and analysis of variance for each one of characters was performed by F–test (Variance Ratio). Difference between treatments was assessed by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

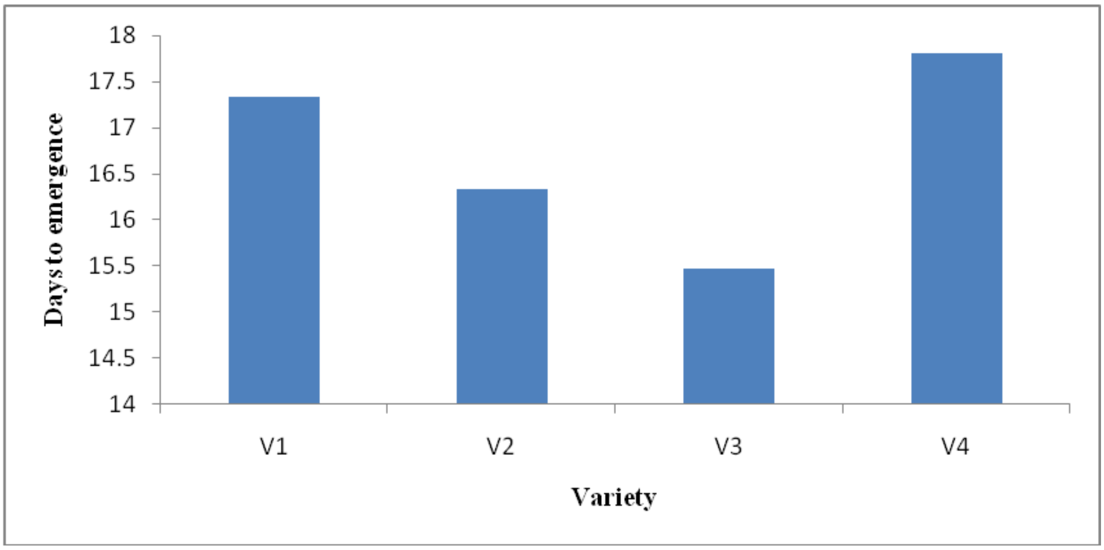
The research work was accomplished to investigate the effect of As on growth, yield and quality of potato in Bangladesh. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The analysis of variance of data respect of all the parameters has been shown in Appendix. 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)

Significant variation in respect of days required for emergence was observed for the different varieties (Appendix II). The maximum days (17.8 days) were required for days to emergence in Granola (V_4) which was statistically similar (17.33 days) to Cardinal (V_1) and the minimum (15.47 days) were taken by Asterix (V_3) (Fig. 1). This result showed that Asterix (V_3) was early emergence variety whereas Granola (V_4) was late one.

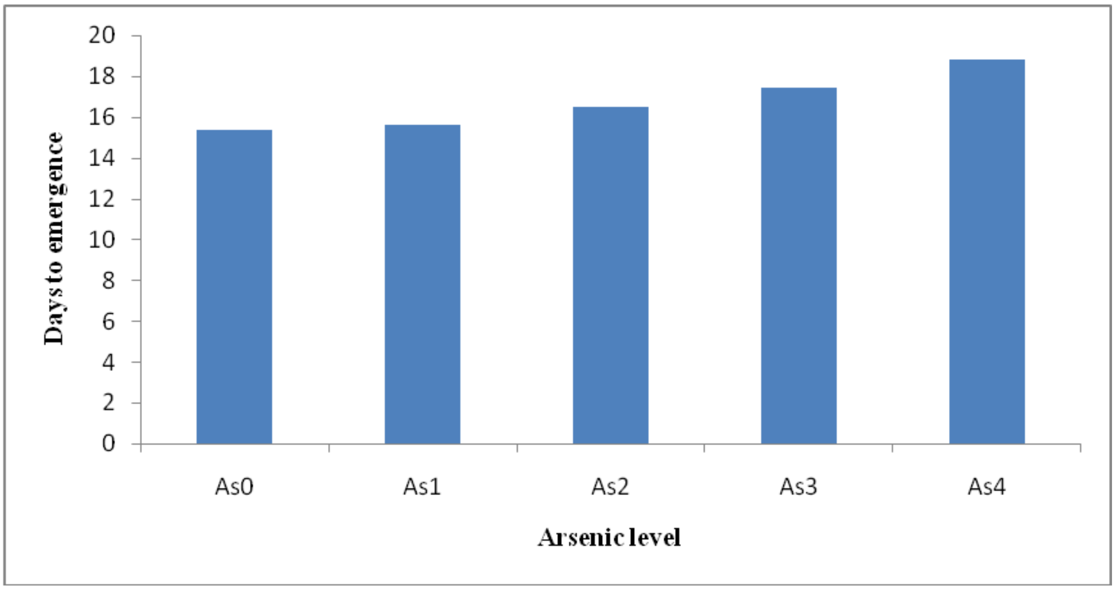
Days to emergence was significantly affected by As levels (Appendix II). The minimum (15.33) days required in As_0 (control) treatment which was statistically similar (15.58 days) to As_1 (10 mg As kg^{-1} soil) treatment and delayed (18.83 days) in As_4 (40 mg As kg^{-1} soil) treatment (Fig. 2). There was significant variation among control and 40 mg As kg^{-1} soil As treatment . Similar trend of result was found by Talukdar (2011), who observed that the mean value of germination percentage, germination index and relative germination rate decreased with concomitant increase of As levels incase of *Trigonella foenum-graecum* L. and *Lathyrus sativus* L. When plants were exposed to excess As either in soil or in solution culture, they exhibited toxicity symptoms such as: inhibition of seed germination (Abedin *et al.,* 2002a).

Combined effect of potato varieties and As levels significantly influenced on days taken to emergence of potato tubers from planting (Appendix II). The treatment combination V_3As_0 required minimum days (13.67) for emergence which was statistically similar (14 days) to V_3As_1 whereas the maximum days (19.67) required for V_4As_4 (Fig. 3).



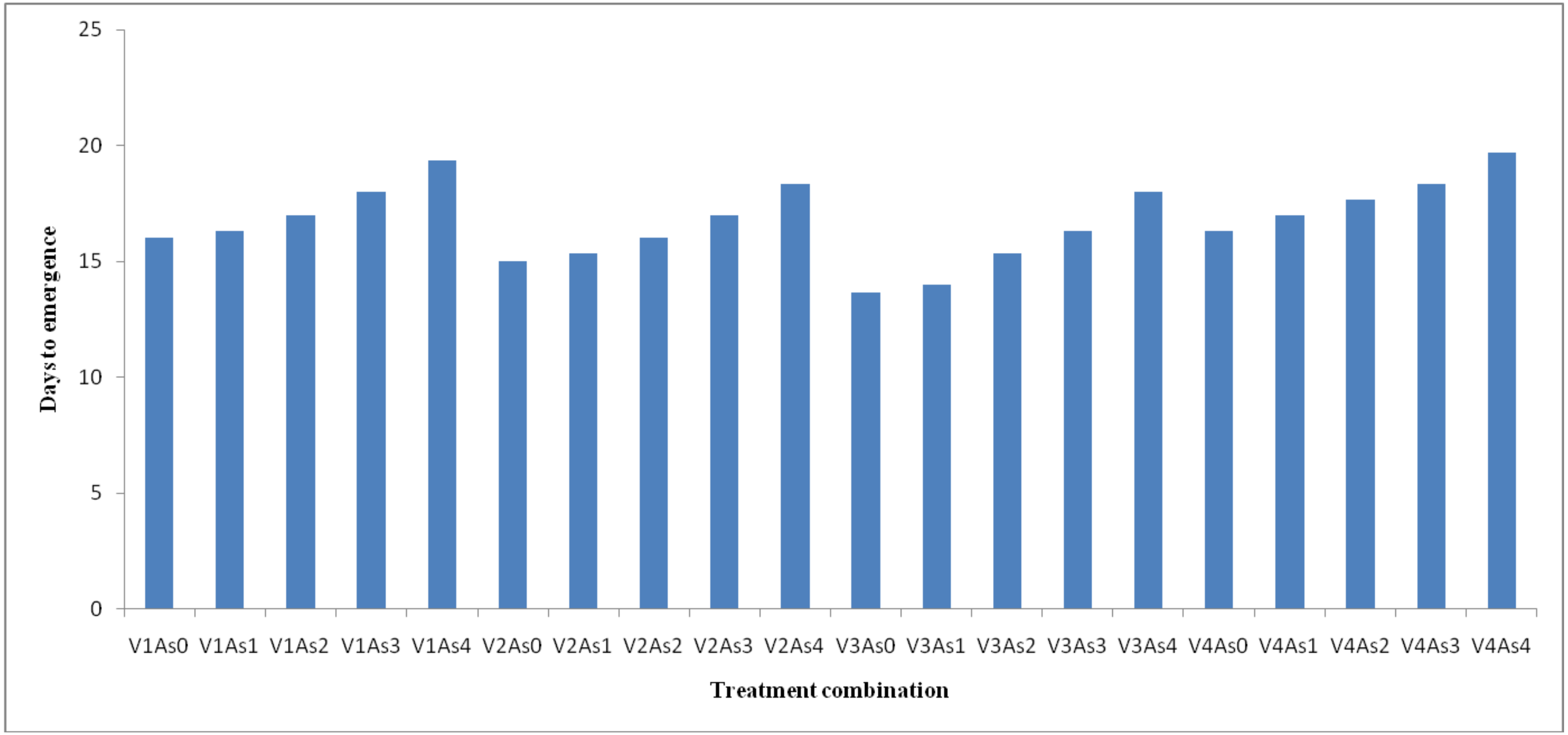
[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola]

Figure 1. Varietal effect on days to emergence. [SE value: 0.29]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 2. Effect of Arsenic levels on days to emergence. [SE value: 0.33]



[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola; As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

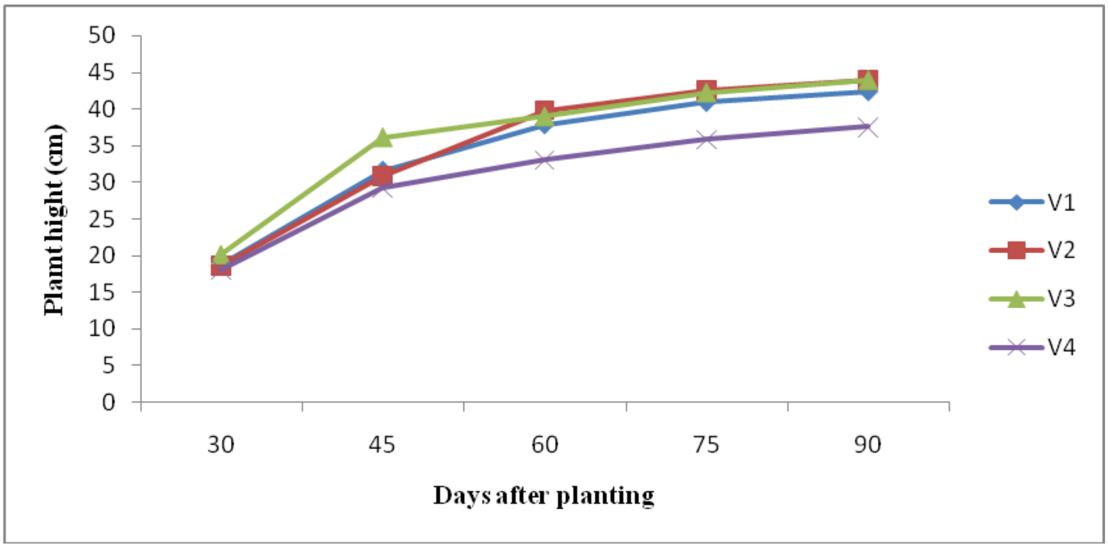
Figure 3. Combined effect of variety and different Arsenic levels on days to emergence. [SE value: 0.66].

4.2 Plant height (cm)

Significant variation was found among the varieties in case of plant height (Appendix III). Plant height of potato exposed statistically significant among V_1, V_2, V_3 and V_4 varieties at 30, 45, 60, 75 and 90 DAP (Figure 4). The variety Diamant (V_2) was accorded the topmost result in terms of plant height (43.97 cm) which was statistically similar (43.93 cm) to Asterix (V_3) whereas Granola (V_4) was scored as the lowest (37.56 cm) at harvesting stage. Islam *et al.* (2009) observed that the Diamant variety produced 48.88 cm plant height where Granola produced 38.50 cm plant height. Hussain *et al.* (1984) reported that the variety Diamant produced the tallest plant. Present investigation referred, Diamant variety exposed best in terms of plant height. The variation in plant height in this finding compared to others findings may be due to pot planting, difference in agro-ecological condition and soils of the experimental site.

Plant height was significantly affected by different As levels (Appendix III). Plant height of potato varieties exposed statistically significant among control (As_0), 10 mg As kg^{-1} soil (As_1), 20 mg As kg^{-1} soil (As_2), 30 mg As kg^{-1} soil (As_3) and 40 mg As kg^{-1} soil (As_4) at 30, 45, 60, 75 and 90 DAP (Figure 5). The tallest plant (47.08 cm) was recorded in 10 mg As kg^{-1} soil (As_1) which was statistically similar (46.42 cm) to control (As_0) while the shortest plant (35.17 cm) was scored in 40 mg As kg^{-1} soil (As_4) at harvesting stage. Sushant and Ghosh (2010) reported that growth of onion plants height were significantly increased with the increasing levels of As in irrigated water and soil; present study also showed that plant height increased up to treated with 10 mg As kg^{-1} soil As treatment and thereafter decreased at higher levels As treatments – 20, 30 and 40 mg As kg^{-1} soil. Growth stimulation by As does not always occur, is sometimes only temporary, and may result in the reduction of top growth. The possibilities exist for growth stimulation by As is displacement of phosphate ions from the soil by arsenate ions, with the resultant increase of phosphate availability (Jacobs and Keeney, 1970). When plants are exposed to excess As either in soil or in solution culture, they exhibit toxicity symptoms such as: decrease in plant height (Abedin *et al.,* 2002b).

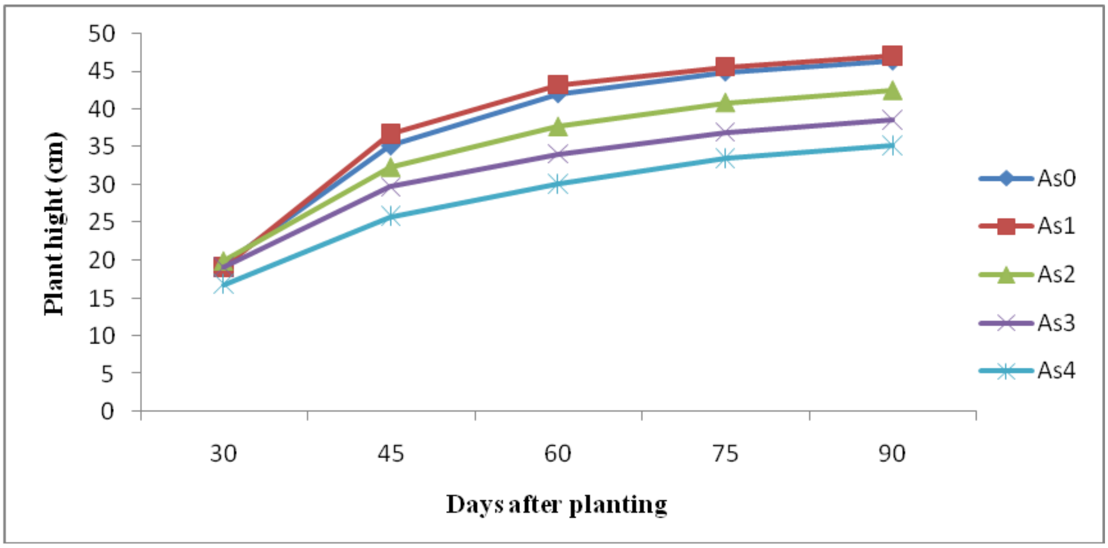
Combined effect of different potato varieties and different As level in terms of plant height also exposed significant variation (Appendix III). Plant height of potato varieties observed statistically significant among treatments at 30, 45, 60, 75 and 90 DAP (Table 1). The tallest plant (49.83 cm) was observed under V_2As_1 which was statistically similar to V_2As_0 (49.67 cm), V_1As_1 (48.50 cm), V_3As_1 (48.67 cm) and V_3As_0 (48.33 cm) while the smallest plant (32.67 cm) was recorded under V_4As_4. The study disclosed that Diamant variety treated with 10 mg As kg^{-1} soil performed the best result in terms of plant height.



[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola]

Figure 4. Varietal performance on plant height at different days after planting (DAP)

[SE value = 0.89, 0.5, 0.4, 0.32 and 0.36 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 5. Effect of Arsenic levels on plant height at different days after planting (DAP)

[SE value = 0.99, 0.56, 0.46, 0.36 and 0. 4 at 30, 45, 60, 75 and 90 DAP, respectively]

Table 1. Combined effect of variety and Arsenic levels on plant height at different days after planting (DAP)

Treatments	Plant height (cm) at different days after planting									
	30		45		60		75		90	
V_1As_0	18.00	a-c	33.17	d-f	42.83	bc	46.00	b	47.33	Bc
V_1As_1	18.50	a-c	35.00	c-e	44.67	ab	47.00	ab	48.50	Ab
V_1As_2	18.00	a-c	32.00	e-g	36.67	fg	39.87	d	40.67	De
V_1As_3	20.33	ab	30.33	f-h	34.33	gh	38.17	de	39.67	De
V_1As_4	19.00	a-c	27.67	h-j	31.00	ij	33.67	f	35.83	G
V_2As_0	18.33	a-c	34.33	c-e	45.17	ab	48.17	a	49.67	A
V_2As_1	16.00	bc	35.33	cd	46.33	a	48.50	a	49.83	A
V_2As_2	22.33	a	30.67	f-h	41.50	cd	43.67	c	45.33	C
V_2As_3	19.50	a-c	28.33	h-j	35.33	gh	38.00	de	39.33	De
V_2As_4	16.67	a-c	25.67	j	30.67	j	34.33	f	35.67	G
V_3As_0	22.33	a	40.17	ab	43.67	bc	46.83	ab	48.33	Ab
V_3As_1	21.67	ab	41.83	a	43.83	a-c	47.50	ab	48.67	Ab
V_3As_2	20.33	ab	37.17	bc	39.50	de	43.17	c	45.50	C
V_3As_3	19.00	a-c	33.33	d-f	36.33	fg	38.83	de	40.67	de
V_3As_4	17.33	a-c	28.17	h-j	31.50	ij	34.83	f	36.50	fg
V_4As_0	19.00	a-c	33.00	d-f	36.67	fg	38.83	de	40.33	de
V_4As_1	20.00	a-c	34.50	c-e	38.00	ef	39.33	d	41.33	d
V_4As_2	19.33	a-c	29.67	g-i	33.33	hi	37.00	e	38.63	ef
V_4As_3	17.33	a-c	26.83	ij	30.33	j	33.00	fg	34.83	gh
V_4As_4	14.33	c	21.83	k	27.00	k	31.00	g	32.67	h
SE Value	1.99		1.13		0.93		0.71		0.8	
CV (%)	18.36		6.14		4.28		3.04		3.32	

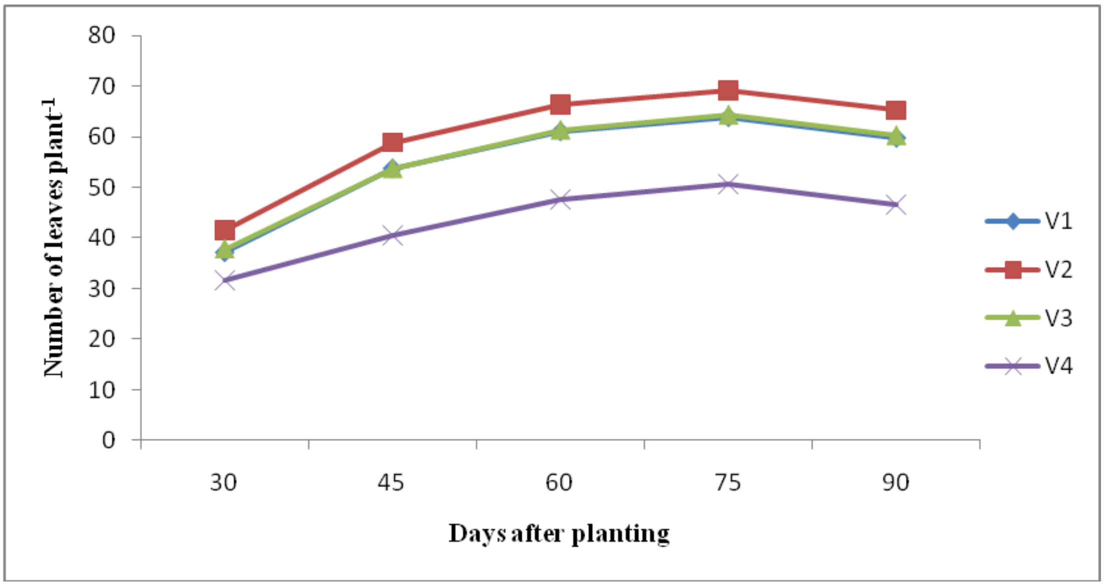
V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.3 Number of leaves plant^{-1}

Leaves number plant^{-1} was significantly affected by the varieties (Appendix IV). Leaves number plant^{-1} of potato varieties showed statistically significant among V_1, V_2, V_3 and V_4 varieties at 30, 45, 60, 75 and 90 DAP (Figure 6). The maximum number of leaves plant^{-1} (65.2) was recorded from Diamant (V_2) variety which was statistically similar (60.3 and 59.7) to Asterix (V_3) and Cardinal (V_1) variety respectively whereas the minimum (46.7) number recorded from Granola (V_4) variety at harvesting stage. The study referred that Diamant variety produce maximum number of leaf.

Leaves number plant^{-1} of potato varieties exposed statistically significant among different As levels at 30, 45, 60, 75 and 90 DAP (Appendix IV). The maximum number of leaves (64.8) was recorded in As_1 (10 mg As kg^{-1} soil) treatment which was statistically similar (64.3) to control treatment, whereas the minimum (45.8) was recorded in As_4 (40 mg As kg^{-1} soil) treatment at harvesting stage (Figure 7). Present study showed that number of leaves plant^{-1} increased up to 10 mg As kg^{-1} soil treatment and thereafter decreased with increasing the As levels.

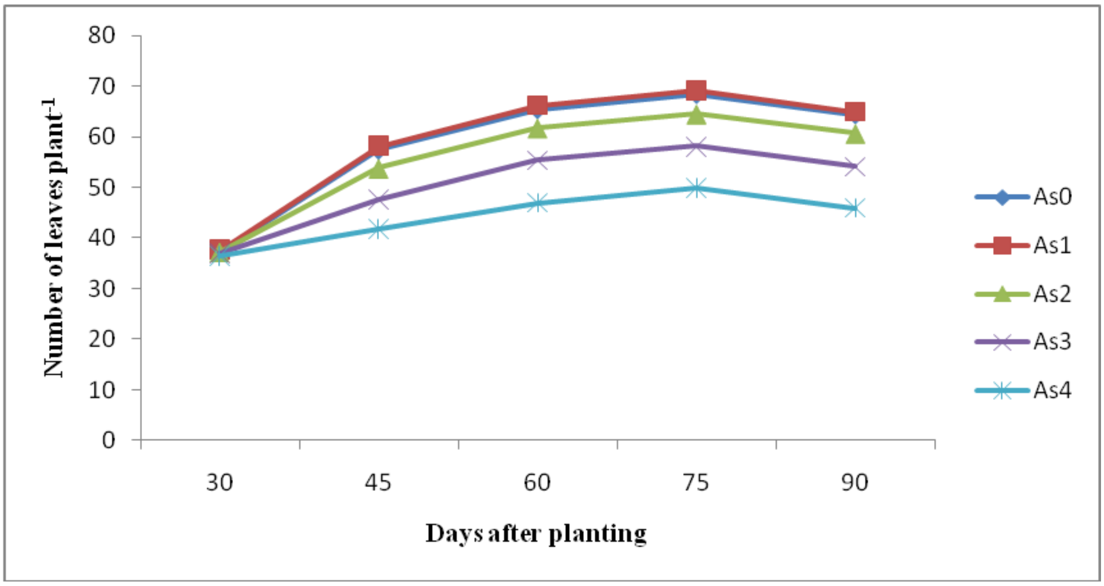
Combined effect of different potato varieties and different As levels in terms of leaf numbers plant^{-1} also exposed significant variation (Appendix IV). Leaf numbers plant^{-1} of potato varieties observed statistically significant among treatments at 30, 45, 60, 75 and 90 DAP (Table 2). The maximum number of leaves plant^{-1} (72) was recorded from V_2As_1 which was statistically similar to V_2As_0 (71.67), V_3As_1 (67), V_1As_1 (67), V_1As_0 (66.67) and V_2As_0 (66.33); whereas the minimum (34.67) recorded from V_4As_4 treatment combination at harvesting stage.



[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola]

Figure 6. Varietal performance on number of leaves plant^{-1} at different days after planting (DAP)

[SE value = 1.4, 1.15, 1.19, 1.17 and 1.15 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 7. Effect of Arsenic levels on number of leaves plant^{-1} at different days after planting (DAP)

[SE value = 1.57, 1.29, 1.33, 1.31 and 1.28 at 30, 45, 60, 75 and 90 DAP, respectively]

Table 2. Combined effect of variety and Arsenic levels on number of leaves plant^{-1} at different days after planting (DAP)

Treatments	Number of leaves plant^{-1} at different days after planting									
	30		45		60		75		90	
V_1As_0	37.00	a-e	59.67	ab	67.67	ab	70.67	ab	66.67	ab
V_1As_1	37.33	a-e	60.00	ab	68.00	ab	71.00	ab	67.00	ab
V_1As_2	37.33	a-e	56.33	bc	64.33	bc	66.33	bc	63.00	bc
V_1As_3	37.33	a-e	49.33	c-e	57.33	cd	60.33	c-e	55.33	d-f
V_1As_4	37.00	a-e	43.33	ef	47.67	ef	50.67	fg	46.67	gh
V_2As_0	42.67	a	64.67	a	72.67	a	75.67	a	71.67	a
V_2As_1	42.67	a	65.67	a	73.67	a	76.67	a	72.00	a
V_2As_2	41.33	ab	60.67	ab	68.67	ab	71.67	ab	67.67	ab
V_2As_3	40.67	a-c	54.33	b-d	62.33	bc	64.33	b-d	61.33	b-d
V_2As_4	40.00	a-d	48.67	de	54.33	de	57.33	d-f	53.33	e-g
V_3As_0	37.00	a-e	59.33	ab	67.33	ab	70.33	ab	66.33	ab
V_3As_1	38.00	a-e	60.33	ab	68.33	ab	71.33	ab	67.00	ab
V_3As_2	38.67	a-e	55.67	b-d	63.67	bc	66.67	bc	62.67	b-d
V_3As_3	37.67	a-e	49.67	c-e	57.67	cd	60.67	c-e	56.67	c-e
V_3As_4	37.67	a-e	43.67	ef	49.67	ef	52.67	fg	48.67	f-h
V_4As_0	32.00	c-e	45.67	e	53.67	de	56.67	ef	52.67	e-g
V_4As_1	32.33	b-e	46.33	e	54.33	de	57.33	d-f	53.33	e-g
V_4As_2	31.33	de	42.33	ef	50.33	d-f	53.33	e-g	49.33	e-h
V_4As_3	32.00	c-e	37.33	fg	44.33	f	47.33	g	43.33	h
V_4As_4	30.67	e	31.00	g	35.67	g	38.67	h	34.67	i
SE Value	0.48		0.38		0.49		0.49		0.49	
CV (%)	14.71		8.64		7.81		7.34		7.67	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ;

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil

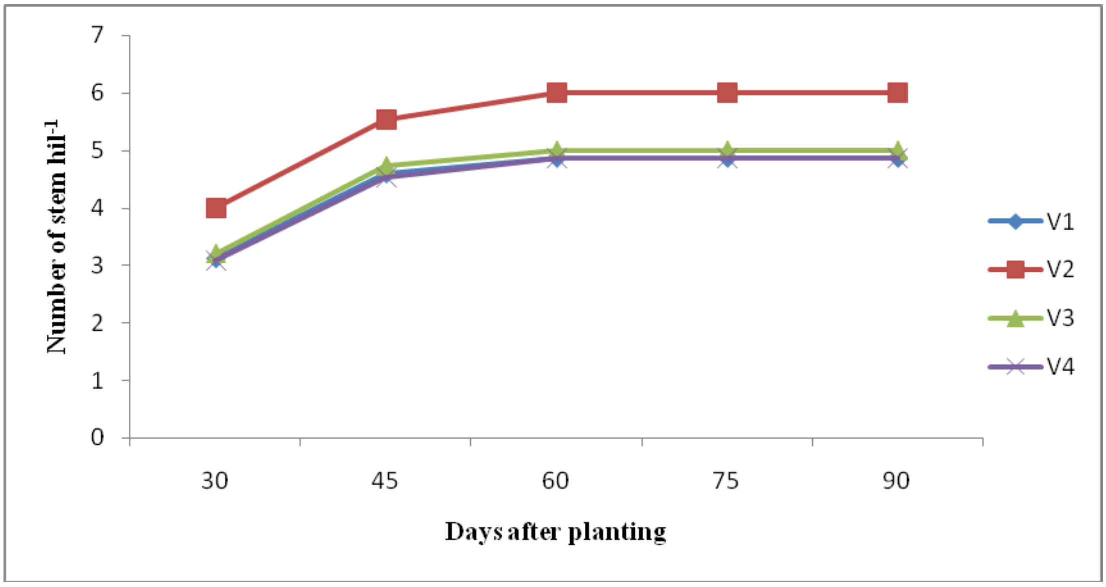
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.4 Number of stems hill^{-1}

Stem numbers hill^{-1} was significantly varied among the varieties (Appendix V). Stem numbers hill^{-1} of potato varieties showed statistically significant among V_1, V_2, V_3 and V_4 varieties at 30, 45, 60, 75 and 90 DAP (Figure 8). The maximum number (6.0) of stems hill^{-1} was recorded from Diamant (V_2) and the minimum (4.87) from Granola (V_4) at harvesting stage which was statistically similar to other varieties. The study referred that Diamant variety produced maximum number of stem hill^{-1}; it may be due to varietal characters.

Stem numbers hill^{-1} of potato varieties exposed statistically significant among different As levels at 30, 45, 60, 75 and 90 DAP (Appendix V). The maximum number (6.42) of stems hill^{-1} was recorded in As_1 (10 mg As kg^{-1} soil) which was statistically similar (6.08) to As_0 (control) treated soil, whereas the minimum (3.75) was recorded in As_4 (40 mg As kg^{-1} soil) at harvesting stage (Figure 9). Study referred that 10 mg As kg^{-1} soil As treatment produced the maximum number of stems. Present study showed that number of stems increased up to 10 mg As kg^{-1} soil treatment and thereafter decreased with increasing the As levels.

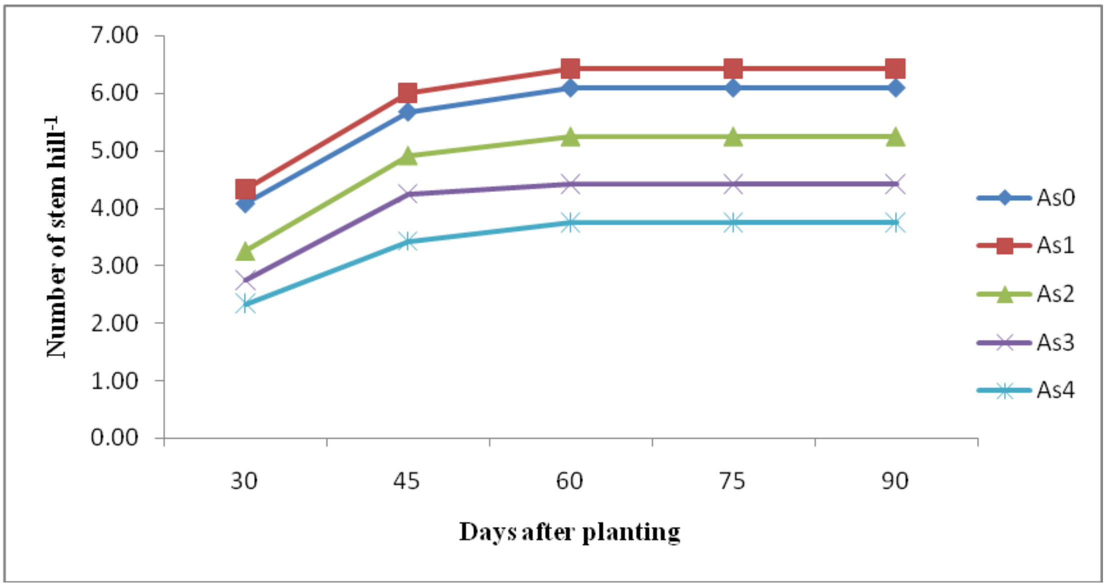
Combined effect of different potato varieties with different As levels in terms of stem numbers also exposed significant variation (Appendix V). Stem numbers of potato varieties observed statistically significant among treatments at 30, 45, 60, 75 and 90 DAP (Table 3). The maximum number of stems (7.33) was achieved from V_2As_1 which was statistically similar (7) to V_2As_0 whereas the minimum (3.33) recorded from V_3As_4.



[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola]

Figure 8. Varietal performance on number of stem at different days after planting (DAP)

[SE value = 0.22, 0.17, 0.22, 0.22 and 0.22 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 9. Effect of Arsenic levels on number of stem at different days after planting (DAP)

[SE value = 0.24, 0.19, 0.25, 0.25 and 0.25 at 30, 45, 60, 75 and 90 DAP, respectively]

Table 3. Combined effect of variety and Arsenic levels on number of stems hill^{-1} at different days after planting (DAP) of potato

Treatments	Number of stems hill^{-1} at different days after planting									
	30		45		60		75		90	
V_1As_0	3.70	b-d	5.33	b-e	5.67	b-d	5.67	b-d	5.67	b-d
V_1As_1	4.00	a-c	5.67	a-d	6.00	a-c	6.00	a-c	6.00	a-c
V_1As_2	3.00	cd	4.67	d-g	5.00	c-f	5.00	c-f	5.00	c-f
V_1As_3	2.70	cd	4.00	f-i	4.00	e-g	4.00	e-g	4.00	e-g
V_1As_4	2.33	d	3.33	hi	3.67	fg	3.67	fg	3.67	fg
V_2As_0	5.00	ab	6.33	ab	7.00	ab	7.00	ab	7.00	ab
V_2As_1	5.33	a	6.67	a	7.33	a	7.33	a	7.33	a
V_2As_2	4.00	a-c	5.67	a-d	6.00	a-c	6.00	a-c	6.00	a-c
V_2As_3	3.33	cd	5.00	c-f	5.33	c-e	5.33	c-e	5.33	c-e
V_2As_4	2.33	d	4.00	f-i	4.33	d-g	4.33	d-f	4.33	d-g
V_3As_0	4.00	a-c	5.67	a-d	6.00	a-c	6.00	a-c	6.00	a-c
V_3As_1	4.00	a-c	6.00	a-c	6.33	a-c	6.33	a-c	6.33	a-c
V_3As_2	3.00	cd	4.67	d-g	5.00	c-f	5.00	c-f	5.00	c-f
V_3As_3	2.67	cd	4.33	e-h	4.33	d-g	4.33	d-g	4.33	d-g
V_3As_4	2.33	d	3.00	i	3.33	g	3.33	g	3.33	g
V_4As_0	3.67	b-d	5.33	b-e	5.67	b-d	5.67	b-d	5.67	b-d
V_4As_1	4.00	a-c	5.67	a-d	6.00	a-c	6.00	a-c	6.00	a-c
V_4As_2	3.00	cd	4.67	d-g	5.00	c-f	5.00	c-f	5.00	c-f
V_4As_3	2.33	d	3.67	g-i	4.00	e-g	4.00	e-g	4.00	e-g
V_4As_4	2.33	d	3.33	hi	3.67	fg	3.67	fg	3.67	fg
SE Value	0.48		0.38		0.49		0.49		0.49	
CV (%)	14.99		13.67		16.63		16.63		16.63	

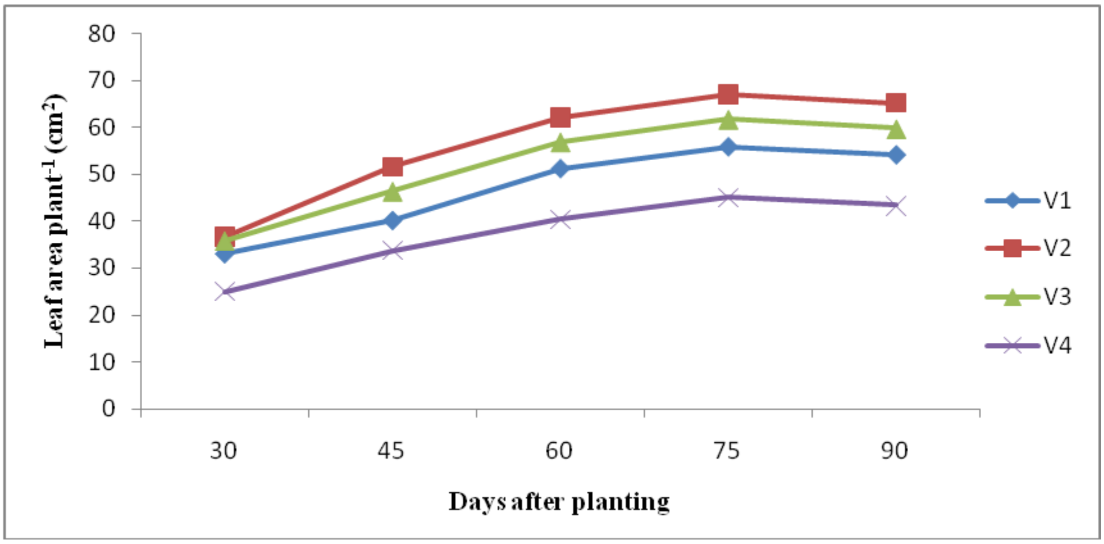
V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.5 Leaf area $plant^{-1}$ (cm^2)

Significant variation was observed among the varieties performance in terms of leaf area $plant^{-1}$ (Appendix VI). Leaf area $plant^{-1}$ of potato exposed statistically significant among V_1, V_2, V_3 and V_4 variety at 30, 45, 60, 75 and 90 DAP (Figure 10). The variety Diamant (V_2) was accorded the topmost result in terms of leaf area $plant^{-1}$ (65.08 cm^2) whereas V_4 (Granola) was scored as the lowest (43.29 cm^2) at harvesting stage. Study referred that the potato variety Diamant exposed best result in terms of leaf area $plant^{-1}$.

Leaf area $plant^{-1}$ was significantly affected by different As levels treatments (Appendix VI). Leaf area $plant^{-1}$ of potato variety exposed statistically significant among As_0 (control), As_1 (10 mg As kg^{-1} soil), As_2 (20 mg As kg^{-1} soil), As_3 (30 mg As kg^{-1} soil) and As_4 (40 mg kg^{-1} soil) at 30, 45, 60, 75 and 90 DAP (Figure 11). The maximum leaf area $plant^{-1}$ (59.96 cm^2) was marked in 10 mg kg^{-1} soil (As_1) treatment that was statistically similar (59.71 cm^2) to control (As_0) treatment and the minimum leaf area $plant^{-1}$ (49.08 cm^2) was scored in 40 mg kg^{-1} soil (As_4) treatment at harvesting stage. Juzl *et al.* (2002) reported that leaf area index of potato plants were significantly decreased with the increasing levels of As in irrigated water and soil but the present study showed that leaf area slightly increased up to treated with 10 mg As kg^{-1} soil and thereafter decreased with increasing the levels of As.

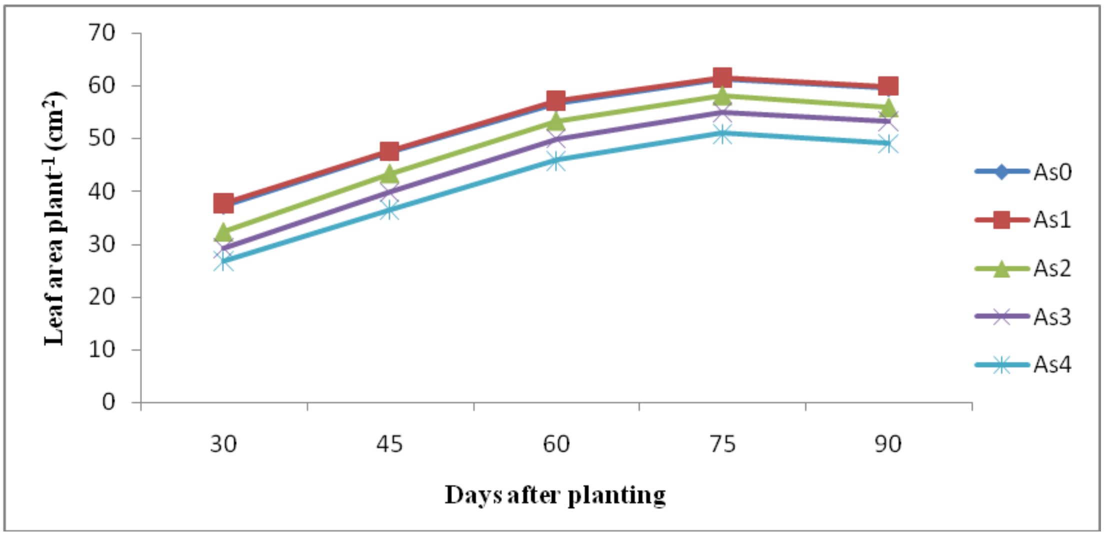
Combined effect of different potato varieties and different As levels in terms of leaf area $plant^{-1}$ also exposed significant variation (Appendix VI). Leaf area $plant^{-1}$ of potato variety observed statistically significant among treatments at 30, 45, 60, 75 and 90 DAP (Table 4). The maximum leaf area $plant^{-1}$ (67.97 cm^2) at 90 DAP was recorded under V_2As_1 that was statistically similar to V_2As_o (67.93 cm^2), V_2As_o (66.13 cm^2) and V_2As_3 (64.85 cm^2) whereas the minimum was (36.33 cm^2) recorded under V_4As_4. The study disclosed that potato variety Diamant cultivated with 10 mg As kg^{-1} soil performed best in terms of leaf area plant^{-1}.



V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola;

Figure 10. Varietal performance on leaf area plant^{-1}at different days after planting (DAP)

[SE value = 0.46, 0.46, 0.47, 0.48 and 0.49 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 11. Effect of As levels on leaf area plant^{-1}at different days after planting (DAP)

[SE value = 0.51, 0.52, 0.52, 0.54 and 0.55 at 30, 45, 60, 75 and 90 DAP, respectively]

Table 4. Combined effect of variety and Arsenic levels on leaf area plant^{-1} at different days after planting (DAP) of potato

Treatments	Leaf area plant^{-1} (cm^2) at different days after planting									
	30		45		60		75		90	
V_1As_0	37.57	c	45.27	c-e	56.07	e	60.48	d	59.07	cd
V_1As_1	37.97	bc	45.33	c-e	56.30	e	60.74	d	59.67	cd
V_1As_2	33.17	de	39.98	f	52.50	fg	56.69	ef	54.37	e
V_1As_3	30.27	e-g	37.10	f	47.13	h	52.20	g	50.50	f
V_1As_4	26.60	hi	33.32	g	44.27	h	49.33	g	47.33	g
V_2As_0	41.60	a	57.23	a	65.37	a	70.31	a	67.93	a
V_2As_1	41.70	a	56.30	a	65.40	a	70.44	a	67.97	a
V_2As_2	36.20	c	52.50	b	63.43	ab	68.31	ab	66.13	ab
V_2As_3	32.40	e-g	47.13	cd	60.37	cd	65.49	bc	64.85	ab
V_2As_4	30.63	e-g	44.27	de	55.43	ef	60.29	d	58.50	cd
V_3As_0	40.53	ab	50.40	b	60.47	b-d	65.28	bc	63.70	b
V_3As_1	40.77	ab	50.50	b	61.10	bc	65.50	bc	63.93	b
V_3As_2	35.73	cd	47.33	c	57.50	de	62.47	cd	59.97	c
V_3As_3	32.53	ef	43.83	e	55.10	ef	59.53	de	56.63	de
V_3As_4	29.50	gh	39.75	f	50.33	g	55.74	f	54.13	e
V_4As_0	29.53	g	37.12	f	45.27	h	49.32	g	48.13	fg
V_4As_1	29.90	fg	37.97	f	45.90	h	49.5	g	48.27	fg
V_4As_2	23.87	ij	33.59	g	39.98	i	45.22	h	43.07	h
V_4As_3	21.37	jk	31.05	gh	37.10	i	42.62	h	40.63	h
V_4As_4	20.20	k	28.77	h	33.32	j	38.43	i	36.33	i
SE Value	1.02		1.03		1.04		1.08		1.09	
CV (%)	5.43		4.18		3.43		3.27		3.41	

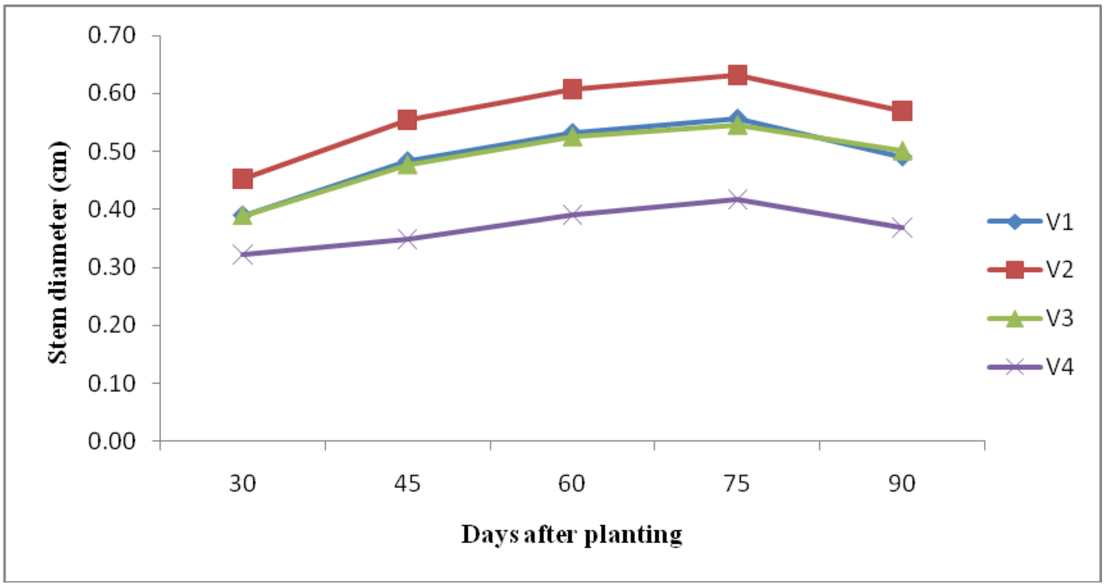
V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.6 Stem diameter (cm)

Significant variation was recorded for stem diameter in different varieties of potato (Appendix VII). Stem diameter of potato varieties exposed significant variation among V_1, V_2, V_3 and V_4 varieties at 30, 45, 60, 75 and 90 DAP (Figure 16). Results indicated that the widest stem diameter (0.57 cm) was recorded from Diamant (V_2) whereas the narrowest (0.37 cm) was recorded from Granola (V_4) at harvesting stage (Figure 12).

Stem diameter showed significant variation with different As levels (Appendix VII). Stem diameter varies with As levels at 30, 45, 60, 75 and 90 DAP (Figure 13). Stem diameter was highest (0.55 cm) in 10 mg As kg^{-1} soil (As_1) which was statistically similar (0.54 cm) to control (As_0) while the narrowest (0.39 cm) was observed in 40 mg As kg^{-1} soil (As_4) at harvesting stage. 10 mg As kg^{-1} soil (As_1) furnished widest diameter of stem from the present study.

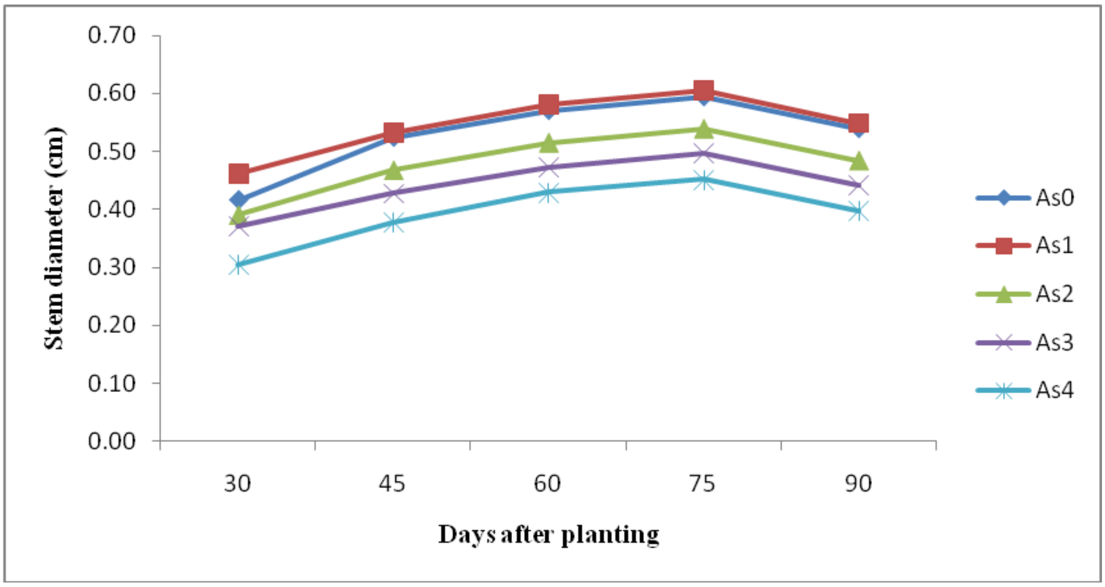
Combined effect of variety and As levels in terms of stem diameter of potato exposed significant variation (Appendix VII). Stem diameter of potato varieties observed statistically significant among treatment combinations at 30, 45, 60, 75 and 90 DAP (Table 5). It was remarked that the widest stem (0.65 cm) was recorded in V_2As_1 which was statistically similar (0.64 cm) to V_2As_0 whereas the narrowest (0.29 cm) was recorded in V_4As_4 at harvesting stage (90 DAP).



[V_1, Cardinal; V_2, Diamant; V_3, Asterix and V_4, Granola]

Figure 12. Varietal performance on stem diameter at different days after planting (DAP)

[SE value = 0.01, 0.008, 0.009, 0.009 and 0.009 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil]

Figure 13. Effect of As levels on stem diameter at different days after planting (DAP)

[SE value = 0.01, 0.009, 0.01, 0.01 and 0.01 at 30, 45, 60, 75 and 90 DAP, respectively]

Table 5. Combined effect of variety and Arsenic levels on Stem diameter at different days after planting (DAP) of potato

Treatments	Stem diameter (cm) at different days after planting									
	30		45		60		75		90	
V_1As_0	0.45	b-d	0.54	b	0.59	b	0.62	b	0.55	bc
V_1As_1	0.47	a-c	0.55	b	0.60	b	0.63	b	0.56	b
V_1As_2	0.38	d-h	0.48	d-f	0.53	d-f	0.56	c-e	0.50	c-e
V_1As_3	0.34	g-k	0.44	f-i	0.48	f-h	0.51	e-g	0.43	f-h
V_1As_4	0.31	i-k	0.40	h-k	0.45	g-j	0.47	f-i	0.41	hi
V_2As_0	0.52	ab	0.63	a	0.67	a	0.70	a	0.64	a
V_2As_1	0.53	a	0.63	a	0.68	a	0.71	a	0.65	a
V_2As_2	0.44	cd	0.54	b	0.59	b	0.61	b	0.56	b
V_2As_3	0.41	c-g	0.51	b-e	0.56	b-d	0.58	b-d	0.52	b-d
V_2As_4	0.36	e-i	0.46	e-g	0.53	d-f	0.55	de	0.48	d-f
V_3As_0	0.43	c-e	0.53	b-d	0.58	b-d	0.60	b-d	0.56	b
V_3As_1	0.43	c-f	0.54	bc	0.59	bc	0.61	bc	0.56	b
V_3As_2	0.38	d-i	0.49	c-f	0.54	c-e	0.56	c-e	0.50	c-e
V_3As_3	0.42	c-f	0.45	f-h	0.49	e-g	0.51	f	0.47	e-g
V_3As_4	0.28	jk	0.38	jk	0.43	i-j	0.45	hi	0.41	hi
V_4As_0	0.26	k	0.40	i-k	0.44	h-j	0.46	g-i	0.41	hi
V_4As_1	0.41	c-f	0.41	g-j	0.46	g-i	0.48	f-h	0.43	g-i
V_4As_2	0.36	f-j	0.36	kl	0.40	jk	0.43	ij	0.38	ij
V_4As_3	0.31	h-k	0.31	lm	0.36	k	0.38	j	0.34	j
V_4As_4	0.27	k	0.27	m	0.30	l	0.33	k	0.29	k
SE Value	0.02		0.019		0.02		0.02		0.02	
CV (%)	10.22		7.36		7.05		6.61		7.08	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.7 Stem dry matter content (%)

This research work exhibited distinct variations in stem dry matter content % of potato varieties (Appendix VIII). The maximum dry matter content of stem (18.41 %) was recorded in Diamant (V_2) whereas, the minimum (15.17 %) was in Granola (V_4) (Table 6).

Dry matter content of stem varied significantly with different As levels (Appendix VIII). The maximum dry matter content (19.66 %) was recorded in 10 mg As kg^{-1} soil (As_1) which was statistically similar (19.36 %) to control (As_0) while, the minimum (13.50 %) was found from 40 mg As kg^{-1} soil (As_4) (Table 7). Carbonell- Barrachina *et al.* (1997) stated that root, stem and leaf dry biomass productions of tomato and bean plants were increased with increasing As levels in the nutrient solution the present experiment showed that shoot dry matter content (%) of potato stem increased up to 10 mg As kg^{-1} soil (As_1) and thereafter decreased with increasing As levels.

Combined effect of variety and As influenced the dry matter content (%) of stem (Appendix VIII). It was observed that the maximum dry matter content of stem (21.28 %) was obtained from V_2As_1 which was statistically similar to V_2As_0 (20.89 %) Whereas; the minimum (11.28 %) was recorded in V_4As_4 (Table 8).

4.8 Tuber flesh dry matter content (%)

This research work showed distinct variations in tuber flesh dry matter content of potato varieties (Appendix VIII). The maximum dry matter content of tuber flesh (18.85 %) was recorded in Cardinal (V_1) whereas, the minimum (17.51 %) were in Diamant (V_2) which was statistically identical with Asterix (V_3) and Granola (V_4) (Table 6).

Dry matter content of tuber flesh varied significantly with different As levels (Appendix VIII). The maximum dry matter content (20.86%) was recorded from 10 mg As kg^{-1} soil (As_1) which was statistically similar to control treatment As_0 (20.81 %) while, the minimum (13.49 %) was recorded in 40 mg As kg^{-1} soil (As_4) (Table 7).

Combined effect of variety and As influenced the dry matter content (%) of tuber flesh (Appendix VIII). The maximum dry matter content of tuber flesh (21.84 %) was obtained from V_2As_1 which was statistically similar to V_2As_0 (21.76 %) and the minimum (11.2 %) was produced by V_4As_4 (Table 8).

4.9 Tuber peel dry matter content (%)

Significant variation was observed among varieties performance in terms of tuber peel dry matter content (%) (Appendix VIII). The maximum dry matter content in tuber peel (10.57 %) was recorded in Diamant (V_2) and the minimum (9.83 %) was in Granola (V_4) variety (Table 6).

Dry matter content of tuber peel varied significantly with different As levels level (Appendix VIII). The maximum dry matter content (11.18 %) was recorded from 10 mg As kg^{-1} soil (As_1) which was statistically similar (11 %) to control (As_0) and the minimum (8.82 %) was recorded in 40 mg As kg^{-1} soil (As_4) (Table 7).

Combined effect of varieties and As levels influenced the dry matter content of tuber peel significantly (Appendix VIII). It was observed that the maximum dry matter content of tuber peel (11.53 %) was obtained from V_2As_1 which was statistically similar to V_3As_1 (11.23 %) and V_1As_1 (11.22 %) whereas; the minimum (8.22 %) was given by V_4As_4 (Table 8).

Table 6. Performance of varieties related to dry matter content

Treatments	Stem dry matter content (%)	Tuber flesh dry matter content (%)	Tuber peel dry matter content (%)
V_1	17.64 b	18.85 a	10.36 b
V_2	18.41 a	17.71 b	10.57 a
V_3	16.87 c	17.51 b	10.25 b
V_4	15.17 d	17.51 b	9.83 c
SE Value	0.25	0.16	0.6
CV (%)	5.73	3.47	2.32

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 7. Effect of Arsenic levels on potato varieties related to dry matter content

Treatments	Stem dry matter content (%)	Tuber flesh dry matter content (%)	Tuber peel dry matter content (%)
As_0	19.36 a	20.81 a	11.00 a
As_1	19.66 a	20.86 a	11.18 a
As_2	17.16 b	18.24 b	10.66 b
As_3	15.43 c	16.07 c	9.60 c
As_4	13.50 d	13.49 d	8.82 d
CV (%)	5.73	3.47	2.32
SE Value	0.26	0.18	0.7

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 8. Combined effect of variety and Arsenic levels related to dry matter content

Treatments	Stem dry matter content (%)		Tuber flesh dry matter content (%)		Tuber peel dry matter content (%)	
V_1As_0	19.98	a-c	20.25	c	11.12	bc
V_1As_1	20.27	a-c	20.55	c	11.22	ab
V_1As_2	17.83	e-g	18.21	de	10.72	d
V_1As_3	16.25	h-j	15.51	gh	9.927	e
V_1As_4	13.85	k	14.01	ij	8.840	f
V_2As_0	20.89	ab	21.76	ab	11.12	bc
V_2As_1	21.28	a	21.84	a	11.53	a
V_2As_2	18.46	d-f	18.99	d	10.93	b-d
V_2As_3	16.38	h-j	16.70	f	10.07	e
V_2As_4	15.06	jk	14.97	hi	9.207	f
V_3As_0	19.03	c-e	20.11	c	11.06	b-d
V_3As_1	19.58	b-d	20.58	c	11.23	ab
V_3As_2	16.81	g-i	17.40	ef	10.76	cd
V_3As_3	15.13	jk	15.66	gh	9.207	f
V_3As_4	13.80	k	13.80	j	8.983	f
V_4As_0	17.54	f-h	20.75	bc	10.72	d
V_4As_1	17.51	f-h	20.86	a-c	10.74	cd
V_4As_2	15.55	ij	18.36	de	10.23	e
V_4As_3	13.97	k	16.39	fg	9.210	f
V_4As_4	11.28	l	11.20	k	8.220	g
SE Value	0.55		0.36		0.14	
CV (%)	5.73		3.47		2.32	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.11 Number of tubers hill^{-1}

Number of tubers hill^{-1} was exposed significantly with potato varieties (Appendix VIII). The maximum number of tubers hill^{-1} (14.33) was recorded in Granola (V_4) which was statistically similar (13.53) to Cardinal (V_1) whereas the minimum number of tubers hill^{-1} (13.13) was in Asterix (V_3) which was statistically similar to Diamant (V_2) (13.40) notified in Table 9.

Different As levels significantly influenced on the number of tubers hill^{-1} (Appendix VIII). 40 mg As kg^{-1} soil (As_4) produced maximum number of tubers hill^{-1} (15.75) while the minimum (12.17) was obtained from the control (As_0) which was statistically similar (12.25) to 10 mg As kg^{-1} soil (As_1) (Table 10). Present study showed that tuber numbers increased with increasing As levels but drastically reduced the size of tuber. Thus the reduced sized tuber hampered on total yield of tuber.

Combined effect of different potato varieties and As levels showed statistically significant variation in number of tubers hill^{-1} (Appendix VIII). The maximum number of tubers hill^{-1} (17.67) was recorded from V_4As_4 which was statistically similar to V_4As_3 (16) while the minimum (11.67) was recorded from V_3As_0 (Table 11).

4.11 Yield of tuber plant^{-1} (g)

It was observed from the results of the present experiment that different potato varieties significantly varied with the tuber yield plant $^{-1}$ (Appendix VIII). The maximum (393.60 g) tuber yield plant $^{-1}$ was recorded in Diamant (V_2) while the minimum (348.15 g) was found in Granola (V_4 (Table 9). The variation in yield in this finding compared to others findings may be due to difference in agro-ecological condition and soils of the experimental site. McLaughlin *et al*. (1994), refers to high variety influence of foreign substances on yield and content of elements in tubers.

Yield of tuber plant^{-1} varied significantly with different As levels (Appendix VIII). The highest tuber yield plant^{-1} (407.40 g) recorded from 10 mg As kg^{-1} soil (As_1) which was statistically similar to control (As_0) (401.70 g) while the minimum (319.50 g) was in 40 mg As kg^{-1} soil (As_4) (Table 10). Carbonell-Barrachina *et al.* (1998) and Gulz, (1999) observed that yield increases due to small additions of As for corn, potatoes, rye and wheat. The decrease in yield was caused by increasing levels of heavy metals. This is in agreement with conclusion by Ducsay (2000) in his work; he refers to phytotoxic effects of heavy metals on plants, which decrease their yields and quality. Growth stimulation by As does not always occur, is sometimes only temporary, and may result in the reduction of top growth. Two possibilities exist for growth stimulation by As: first, stimulation of plant systems by small amount of As, since other pesticides, such as 2, 4-D, stimulate plant growth at sub-lethal dose levels (Woolson *et al*., 1971b); second, displacement of phosphate ions from the soil by arsenate ions, with the resultant increase of phosphate availability (Jacobs and Keeney, 1970). In this present experiment application of 10 mg As kg^{-1} soil increased the most yield contributing characters; thus yield increased 1.42 % over control.

Treatment combination of potato varieties and different As levels influenced the yield of tuber plant^{-1} significantly (Appendix VIII). The yield of tuber plant^{-1} was observed maximum in V_2As_1 (438.00 g) treatment combination which was statistically similar to V_2As_0 (432.75 g) while the minimum (290.25 g) was found under V_4As_4 treatment combination (Table 11).

Table 9. Performance of varieties related to number of tubers hill^{-1} and yield

Treatments	Number of tubers hill^{-1}	Yield of tuber plant^{-1} (g)
V_1	13.53 ab	365.55 b
V_2	13.40 b	393.60 a
V_3	13.13 b	364.35 b
V_4	14.33 a	348.15 c
SE Value	0.3	0.21
CV (%)	8.59	5.15

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 10. Effect of Arsenic levels related to number of tubers hill^{-1} and yield

Treatments	Number of tubers hill^{-1}	Yield of tuber plant^{-1} (g)
As_0	12.17 d	401.70 a
As_1	12.25 d	407.40 a
As_2	13.25 c	365.85 b
As_3	14.58 b	345.00 c
As_4	15.75 a	319.50 d
SE Value	0.34	0.24
CV (%)	8.59	5.15

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola;
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 11. Combined effect of variety and Arsenic levels related to number of tubers hill^{-1} and yield

Treatments	Number of tubers hill^{-1}	Yield of tuber plant^{-1} (g)
V_1As_0	12.33 f-h	389.70 cd
V_1As_1	12.67 e-h	395.85 b-d
V_1As_2	13.33 d-h	366.15 e-g
V_1As_3	14.00 c-f	349.20 g-i
V_1As_4	15.33 b-c	327.30 jk
V_2As_0	12.33 f-h	432.75 a
V_2As_1	12.33 f-h	438.00 a
V_2As_2	12.67 e-h	385.35 de
V_2As_3	14.33 b-e	363.00 fg
V_2As_4	15.33 bc	348.60 g-i
V_3As_0	11.67 h	406.65 bc
V_3As_1	12.00 gh	410.85 b
V_3As_2	13.33 d-h	357.75 fg
V_3As_3	14.00 c-f	334.50 h-j
V_3As_4	14.67 b-d	311.85 k
V_4As_0	12.00 gh	377.55 d-f
V_4As_1	12.33 gh	384.75 de
V_4As_2	13.67 c-g	354.45 gh
V_4As_3	16.00 ab	333.45 ij
V_4As_4	17.67 a	290.25 l
SE Value	0.67	0.48
CV (%)	8.59	8.59

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.12 Grade of tubers (on the basis of size in diameter)

On the basis of size in diameter tubers have been graded into A (>55mm), B (45-55mm), C (28-45mm) and D (<28mm). The results indicate that there was significant difference in the varietal effect in respect of production of different grades of tubers (Appendix IX). Among the variety Granola (V_4) produced the maximum (28.06%) biggest size that was A grade (>55mm), Diamant (V_2) produce (48.07%) B grade (45-55mm) size tubers and (29.94%) C grade (28-45mm) size tuber whereas the maximum D grade (<28mm) size tuber (9.62%) produce in Granola (V_4) (Table 12).

Grade of tuber was significantly affected by As levels (Appendix IX). It was observe that the maximum (23.50%) A grade (>55mm) tuber produce in control (As_0) which was statistically similar (23.13%) to 10 mg As kg^{-1} soil (As_1), this trend also found in B grade (45-55mm) tuber. 40 mg As kg^{-1} soil (As_4) produced the maximum (31.24%) C grade (28-45mm) size tuber and (10.65%) D grade (<28mm) size tuber (Table 13). The quality of A grade and B grade tubers remarkably decreased with the increase As levels. Therefore with the increase of As levels C grade and D grade tuber remarkably increases.

Combined effect of different potato varieties and As levels showed statistically significant variation grade of tubers (Appendix IX). The maximum (30.8%) A grade (>55mm) size tuber was recorded from V_4As_0 which was statistically similar to V_4As_1 (29.54%). V_2As_1 produced the maximum (50.40%) B grade (45-55mm) size tuber which were statistically similar to V_2As_0 (50.05%) and V_2As_2 (48.49%). V_2As_4 produced the highest (32.36%) C grade (28-45mm) size tuber which was statistically similar to V_2As_3 (31%), V_4As_4 (31.12%) and V_2As_3 (31%) respectively. Whereas the V_4As_4 produced the highest (11.64%) D grade (<28mm) size tuber (Table 14).

Table 12. Performance of varieties related to grade of tubers (on the basis of size in diameter)

Treatments	Grade-A (%)		Grade-B (%)		Grade-C (%)		Grade-D (%)	
V_1	22.61	c	41.67	b	27.21	b	8.502	B
V_2	14.00	d	48.07	a	29.94	a	7.991	C
V_3	23.84	b	40.88	b	26.64	b	8.635	B
V_4	28.06	a	37.14	c	25.19	c	9.616	A
SE Value	0.38		0.3		0.23		0.1	
CV (%)	6.71		2.79		3.34		4.48	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 13. Effect of Arsenic levels on potato varieties related to grade of tubers (on the basis of size in diameter)

Treatments	Grade-A (%)		Grade-B (%)		Grade-C (%)		Grade-D (%)	
As_0	23.50	a	44.29	a	24.77	d	7.438	D
As_1	23.13	a	44.44	a	25.02	d	7.414	D
As_2	22.35	ab	42.32	b	26.64	c	8.687	C
As_3	21.84	b	40.35	c	28.57	b	9.243	B
As_4	19.82	c	38.29	d	31.24	a	10.65	A
SE Value	0.43		0.34		0.26		0.11	
CV (%)	6.71		2.79		3.34		4.48	

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil and As_4, 40 mg As kg^{-1} soil
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 14. Combined effect of variety and Arsenic levels related to grade of tubers (on the basis of size in diameter)

Treatments	Grade-A (%)		Grade-B (%)		Grade-C (%)		Grade-D (%)	
V_1As_0	23.96	cd	43.31	cd	25.47	fg	7.26	Ij
V_1As_1	23.97	cd	43.35	cd	25.57	fg	7.12	J
V_1As_2	23.28	cd	41.62	de	26.68	ef	8.42	Fg
V_1As_3	22.19	d	40.70	ef	28.01	de	9.10	De
V_1As_4	19.67	e	39.38	f-h	30.33	bc	10.62	B
V_2As_0	14.53	f	50.05	a	28.49	d	6.93	J
V_2As_1	14.16	f	50.40	a	28.58	d	6.86	J
V_2As_2	13.95	f	48.89	a	29.28	cd	7.87	g-i
V_2As_3	13.88	f	46.82	b	31.00	ab	8.30	Fg
V_2As_4	13.46	f	44.18	c	32.36	a	9.99	Bc
V_3As_0	24.73	c	44.07	c	23.73	hi	7.47	h-j
V_3As_1	24.83	c	44.10	c	23.67	hi	7.40	Ij
V_3As_2	23.97	cd	41.23	ef	26.05	fg	8.75	Ef
V_3As_3	23.67	cd	38.50	gh	28.61	d	9.22	De
V_3As_4	22.02	de	36.50	ij	31.13	ab	10.34	Bc
V_4As_0	30.80	a	39.72	e-g	21.39	j	8.09	Gh
V_4As_1	29.54	ab	39.92	e-g	22.25	ij	8.28	Fg
V_4As_2	28.18	b	37.56	hi	24.55	gh	9.71	Cd
V_4As_3	27.61	b	35.39	j	26.64	ef	10.36	B
V_4As_4	24.14	cd	33.10	k	31.12	ab	11.64	A
SE Value	0.86		0.68		0.52		0.22	
CV (%)	6.71		2.79		3.34		4.48	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ; As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil & As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.13 Grade of tubers (On the basis of weight)

On the basis of weight tubers have been graded into marketable tuber (>20g) and non-marketable tuber (<20g). The results indicate that there was significant difference in the varietal effect in respect of production of two grades of tubers (Appendix X). Among the variety Diamant (V_2) produced the maximum (92.01%) marketable tuber while Granola (V_4) produced minimum (90.38%) (Table 15).

Grade of tuber was significantly affected by As levels (Appendix X). It was observed that the maximum (92.59%) marketable potato produce in control (As_0) which was statistically similar to 10 mg As kg^{-1} soil (As_1) (92.56%) whereas the minimum (89.35%) found in 40 mg As kg^{-1} soil (As_4) (Table 16). The quality of marketable tuber percentage remarkably decreased with the increasing the As levels.

Combined effect of different potato varieties and As levels showed statistically significant variation on grade of tubers on the basis of marketable/ non-marketable tuber percentages (Appendix X). The maximum (93.14%) marketable potato tuber was recorded from V_2As_0 which was statistically similar to V_2As_1 (93.07%), V_1As_1 (92.88%) and V_1As_1 (92.74%), respectively and the minimum (88.36%) was found in V_4As_4 (Table 17).

Table 15. Performance of varieties related to grade of tubers (On the basis of weight)

Treatments	Marketable tuber (%)	Non-marketable tuber (%)
V_1	91.50 b	8.50 B
V_2	92.01 a	7.99 C
V_3	91.36 b	8.64 B
V_4	90.38 c	9.62 A
SE Value	0.1	0.1
CV (%)	0.43	4.48

V_1, Cardinal; V_2, Diamont V_3, Asterix and V_4, Granola

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 16. Effect of Arsenic levels on grade of tubers (On the basis of weight)

Treatments	Marketable tuber (%)	Non-marketable tuber (%)
As_0	92.59 a	7.41 D
As_1	92.56 a	7.44 D
As_2	91.31 b	8.69 C
As_3	90.76 c	9.24 B
As_4	89.35 d	10.65 A
SE Value	0.11	0.11
CV (%)	0.43	4.48

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil & As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 17. Combined effect of variety and Arsenic levels related to grade of tubers (On the basis of weight)

Treatments	Marketable tuber (%)		Non-marketable tuber (%)	
V_1As_0	92.88	a	7.12	J
V_1As_1	92.74	ab	7.26	Ij
V_1As_2	91.58	de	8.42	Fg
V_1As_3	90.90	fg	9.1	De
V_1As_4	89.38	i	10.6	B
V_2As_0	93.14	a	6.86	J
V_2As_1	93.07	a	6.93	J
V_2As_2	92.13	b-d	7.87	g-i
V_2As_3	91.70	de	8.3	Fg
V_2As_4	90.01	hi	9.99	Bc
V_3As_0	92.60	ab	7.4	Ij
V_3As_1	92.53	a-c	7.47	h-j
V_3As_2	91.25	ef	8.75	Ef
V_3As_3	90.78	fg	9.22	De
V_3As_4	89.66	hi	10.34	Bc
V_4As_0	91.91	cd	8.09	Gh
V_4As_1	91.72	de	8.28	Fg
V_4As_2	90.29	gh	9.71	Cd
V_4As_3	89.64	i	10.36	B
V_4As_4	88.36	j	11.64	A
SE Value	0.22		0.22	
CV (%)	0.43		4.48	

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola
As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil & As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.14 Arsenic content of tuber peel

This research work exhibited distinct variations in As content in tuber peel of different varieties (Appendix X). The maximum As content of tuber peel (2.89 mg kg^{-1}) was recorded in Granola (V_4) whereas the minimum (2.01 mg kg^{-1}) was in Diamant (V_2) (Table 18).

As levels of tuber peel varied significantly with different As levels (Appendix X). The maximum As content (5.52 mg kg^{-1}) of tuber peel was recorded in 40 mg As kg^{-1} soil (As_4) while the minimum (0 mg kg^{-1}) was in control (As_0) (Table 19).

Combined effect of potato varieties and As levels influenced the As content of potato peel significantly (Appendix X). It was observed that the maximum As content (6.27 mg kg^{-1}) of potato peel was obtained from V_4As_4 whereas the minimum (0.00) was recorded from all control treatment combinations like V_1As_0, V_2As_0, V_3As_0 and V_4As_0 (Table 20).

4.15 Arsenic content of tuber flesh

As levels of tuber was influenced significantly by potato varieties (Appendix X). Granola (V_4) accumulated the maximum As concentration (0.13 mg kg^{-1}) whereas the minimum As content (0.08 mg kg^{-1}) was obtained by Diamant (V_2) which was statistically similar (0.10 mg kg^{-1}) to Cardinal (V_1) (Table 18). According to the present study, Granola variety accumulated maximum As in flesh.

As levels of tuber varied significantly with application of different As levels (Appendix X). The maximum As concentration (0.19 ppm) accumulates in 40 mg As kg^{-1} soil (As_4) while the lowest (0 mg kg^{-1}) was found in control (As_0) (Table 19). Comparison of As accumulation of different plant parts of potato clearly showed that translocation of As in edible parts was relatively lower than the any other plant parts. Arsenic accumulation of different plant parts was in the following sequence: root > stem > leaf > tuber, irrespective of all cultivars (Rajib *et al*., 2012). Higher content of As in soils also causes higher absorption of this element by roots, which are damaged and plants are limited in growth (Onken and Hossner 1995).

Combination of variety and As levels influenced As accumulation of tuber flesh (Appendix X). The maximum As content (0.22 mg kg^{-1}) was found from V_4As_4 which were statistically similar to V_4As_3 (0.19 mg kg^{-1}) and V_1As_4 (0.18 mg kg^{-1}) respectively whereas the minimum (0.05 mg kg^{-1}) recorded in V_2As_1 except (0 mg kg^{-1}) control combinations (V_1As_0, V_2As_0, V_3As_0, and V_4As_0) (Table 20). The amount of As accumulated by Diamant variety with application of 10 mg As kg^{-1} soil was same as Chinese food safety standards of inorganic arsenic for vegetables (0.05 mg kg^{-1}).

Table 18. Effect of varieties related to As accumulation

Treatments	Arsenic content of tuber peel (mg kg^{-1})	Arsenic content of tuber flesh (mg kg^{-1})
V_1	2.12 c	0.10 b
V_2	2.01 d	0.08 b
V_3	2.26 b	0.11 ab
V_4	2.89 a	0.13 a
SE Value	0.38	0.004
CV (%)	6.31	16.83

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 19. Effect of Arsenic levels on As accumulation

Treatments	Arsenic content of tuber peel (mg kg^{-1})	Arsenic content of tuber flesh (mg kg^{-1})
As_0	0.00 e	0.00 e
As_1	0.83 d	0.07 d
As_2	1.44 c	0.12 c
As_3	3.82 b	0.15 b
As_4	5.52 a	0.19 a
SE Value	0.42	0.005
CV (%)	6.31	16.83

As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil & As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 20. Combined effect of variety and Arsenic levels related to As accumulation

Treatments	Arsenic content of tuber peel (mg kg^{-1})	Arsenic content of tuber flesh (mg kg^{-1})
V_1As_0	0.00 j	0.00 g
V_1As_1	0.80 i	0.06 f
V_1As_2	1.28 gh	0.12 c-e
V_1As_3	3.30 e	0.15 b-d
V_1As_4	5.23 c	0.18 ab
V_2As_0	0.00 j	0.00 g
V_2As_1	0.60 i	0.05 fg
V_2As_2	1.17 gh	0.10 d-f
V_2As_3	3.23 e	0.12 c-e
V_2As_4	5.07 c	0.16 bc
V_3As_0	0.00 j	0.00 g
V_3As_1	0.80 i	0.08 ef
V_3As_2	1.40 g	0.12 c-e
V_3As_3	3.60 d	0.16 bc
V_3As_4	5.50 b	0.19 ab
V_4As_0	0.00 j	0.00 g
V_4As_1	1.13 h	0.09 ef
V_4As_2	1.90 f	0.15 b-d
V_4As_3	5.13 c	0.19 ab
V_4As_4	6.27 a	0.22 a
SE Value	0.85	0.01
CV (%)	6.31	16.83

V_1, Cardinal; V_2, Diamant V_3, Asterix and V_4, Granola ; As_0, Control; As_1, 10 mg As kg^{-1} soil; As_2, 20 mg As kg^{-1} soil; As_3, 30 mg As kg^{-1} soil & As_4, 40 mg As kg^{-1} soil

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

CHAPTER V

SUMMARY AND CONCLUSION

In order to produce potato under As contaminated soil with low risk for Bangladeshi farmers, a research was conducted to investigate the growth, yield and quality of potato varieties under As contaminated soil at Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka during period from November 2011 to February 2012. Two factor experiment included 4 potato varieties viz. V_1 (Cardinal), V_2 (Diamant), V_3 (Asterix), V_4 (Granola) and 5 Arsenic levels viz. As_0 (Control), As_1 (10 mg As kg^{-1} soil), As_2 (20 mg As kg^{-1} soil), As_3 (30 mg As kg^{-1} soil), As_4 (40 mg As kg^{-1} soil) was outlined in Randomized Complete Block Design (RCBD) with three replications.

The data on crop growth and yield parameters like days to first emergence, plant height, number of leaves $plant^{-1}$, leaf area, number of stems $hill^{-1}$, stem diameter and dry matter content (%) of stem were recorded at different growth stages. Dry matter content (%) of tuber flesh, tubers peel dry matter content (%), number of tubers $hill^{-1}$ and tuber yield were recorded after harvesting. Quality character parameters like grade of tuber i. grade of tubers (on the basis of size in diameter) and ii. Grade of tubers (on the basis of weight), As content of potato peel, As content of tuber flesh after harvesting. Collected data were statistically analyzed for the evaluation of treatments for the identification of the best variety of potato, the save As concentration and the best combination. Summary of the results and conclusion have been described in this chapter.

Results showed that variety had significant effect on growth parameters. The rapid increase of plant height was observed from 30 days to 90 days of growth stages which was the highest (43.97 cm) in the Diamant (V_2) and smallest (37.56 cm) in Granola (V_4) at harvesting stage. Conversely, 10 mg As kg^{-1} soil (As_1) and 40 mg As kg^{-1} soil (As_4) were marked as tallest (47.08 cm) and shortest (35.17 cm) plant respectively at harvesting stage in terms of As levels.

In combination of potato variety and As levels, V_2As_1 generated tallest (49.83 cm) plant whereas V_4As_4 produced shortest (32.67 cm) at harvesting stage.

In potato varieties, Asterix (V_3) provided the lowest period (15.47 days) for days to emergence whereas Granola (V_4) provided maximum period (17.33 days). Regarding on As concentration, As_0 (control) treatment have need of less time (15.33 days) for days to emergence while 40 mg As kg^{-1} soil (As_4) provided maximum period (18.33 days). In combination, V_3As_0 was taken earliest period (13.67 days) and V_4As_4 was taken delayed period (19.67 days) in terms of days to emergence.

Considering the varieties, Diamant (V_2) generated the widest stem diameter (0.57 cm) and largest leaf area $plant^{-1}$ (65.08 cm^2) at harvesting stage whereas Granola (V_4) produced the narrowest stem diameter (0.37 cm) and smallest leaf area $plant^{-1}$ (43.29 cm^2) at harvesting stage. Regarding on As concentration, 10 mg As kg^{-1} soil (As_1) produced widest stem diameter (0.55 cm) and largest leaf area $plant^{-1}$ (59.96 cm^2) while lowest stem diameter (0.39 cm) and smallest leaf area $plant^{-1}$ (49.08 cm^2) given by 40 mg As kg^{-1} soil (As_4) at harvesting stage. In combination V_2As_1 gave widest diameter (0.65 cm) and largest leaf area $plant^{-1}$ (67.97 cm^2) while V_4As_4 produced the narrowest diameter (0.29 cm) and smallest leaf area $plant^{-1}$ (36.33 cm^2) at harvesting stage.

Considering the varietal characteristics, the maximum number of leaves $plant^{-1}$ (65.2) and stems $hill^{-1}$ (6) was generated by Diamant (V_2) and the minimum number leaves (46.7) and stems (4.87) was produced by Granola (V_4) at harvesting stage. Whereas observing the As treated soil, 10 mg As kg^{-1} soil (As_1) generated the maximum number of leaves (64.8) and stems (6.42) whereas 40 mg As kg^{-1} soil (As_4) produced the minimum number of leaves (45.8) and stems (3.75). In combination V_2As_1 generated utmost number of leaves $plant^{-1}$ (72) and stems $hill^{-1}$ (7.33) whereas the minimum number of leaves (34.67) from V_4As_4 and stems (3.33) from V_3As_4 at harvesting stage.

Among the varieties, the maximum dry matter content (%) of stem (18.41 %), tuber peel (10.57 %) and tuber flesh (18.85 %) produced by Diamant (V_2) variety and the minimum dry matter content (%) of stem (15.17 %), tuber peel (9.83 %) and tuber flesh (17.51 %) generate by Granola (V_4). Whereas observing the As treated soil, 10 mg As kg^{-1} soil (As_1) generated maximum dry matter content (%) of stem (19.66 %), tuber peel (11.18 %) and tuber (20.86 %); on the other hand 40 mg As kg^{-1} soil (As_4) produced the minimum dry matter content (%) of stem (13.5 %), tuber peel (8.82 %) and tuber (13.49 %). In combination V_2As_1 treatment generated the maximum dry matter content of stem (21.28 %), tuber peel (11.53 %) and tuber flesh (21.84 %) and the minimum dry matter content of stem (11.28 %), tuber peel (8.22 %) and tuber (11.2 %) generate by V_4As_4 treatment at harvesting stage.

Considering the varieties, Granola (V_4) produced utmost number of tubers (14.33) and Asterix (V_3) produced least (13.13). Whereas observing As concentration, 40 mg As kg^{-1} soil (As_4) provided the maximum number of tubers (15.75) and minimum (12.17) produced by As_0 (control) treatment. Conversely, V_4As_4 generated the maximum number of tubers (17.67) and the minimum (11.67) produced by V_3As_0.

Among the varieties, the maximum yield $plant^{-1}$ (393.60 g) was recorded in Diamant (V_2) and the minimum (348.15 g) from Granola (V_4). Whereas observing the As treated soil, 10 mg As kg^{-1} soil (As_1) generated the maximum yield $plant^{-1}$ (407.40 g) which was statistically similar to As_0 (control) treatment (401.70 g) while the minimum (319.50 g) was found in 40 mg As kg^{-1} soil (As_4). In combination of potato variety and As levels, V_2As_1 generated the maximum yield $plant^{-1}$ (438.00 g) which was statistically similar to V_2As_0 (432.75 g) whereas the minimum (290.25 g) from V_4As_4.

Significant variation also found among different varieties on different grades of tubers (marketable/non-marketable tuber %). The highest percentage (92.01) of marketable tuber produced by Diamant (V_2) while the lowest (90.38) was recorded in Granola (V_4). Regarding on As concentration, As_0 (control) treated soil produced the highest percentage (92.59) of marketable tuber while the lowest (89.35) produced by 40 mg As kg^{-1} soil (As_4). In combination of potato variety and arsenic levels, V_2As_1 generated highest percentage (93.14) of marketable tuber whereas lowest (88.36) was produced by V_4As_4.

Among the potato varieties, the maximum As accumulated by tuber flesh and tuber peel (0.13 mg kg^{-1} and 2.89 mg kg^{-1}, respectively) generated by Granola (V_4) and the lowest (0.08 mg kg^{-1} and 2.01 mg kg^{-1}, respectively) was found in Diamant (V_2). Whereas observing the As treated soil, the maximum As accumulated by tuber flesh and tuber peel (0.19 mg kg^{-1} and 5.52 mg kg^{-1} respectively) at 40 mg As kg^{-1} soil (As_4) while the minimum from control (As_0). In combination of potato variety and arsenic levels, V_4As_4 accumulated the maximum As in both tuber flesh and tuber peel (0.22 mg kg^{-1} and 6.27 mg kg^{-1}, respectively) and the minimum in control treatment combinations (V_1As_0, V_2As_0, V_3As_0 and V_4As_0).

Considering the results of the present experiment, it may conclude that As positively influenced the entire physiology, growth and yield of potato up to 10 mg As kg^{-1} soil (As_1) but finally decreased with increasing As levels in soil. As accumulation increased with the increasing As levels. It was also observed that Diamant (V_2) variety accumulated lesser amount of arsenic in their edible parts than other variety did, which was less than critical level (0.15 mg kg^{-1}) for human body and had also a higher yielding capacity. So, it may be recommended that Diamant (V_2) variety with As concentration up to 10 mg As kg^{-1} soil (As_1) is not harmful for growth and yield of potato and showed to be drastically affected by increased As concentration treatment.

However, to reach a specific recommendation, more experiment on As contaminated soil will be conducted at different As prone areas of Bangladesh for selecting suitable As tolerance potato variety(s).

REFERENCES

Abedin, M.J. and Meharg, A.A. (2002a). Relative toxicity of arsenite and arsenate on germination and early seedling growth of rice (*Oryza sativa* L.). *Plant Soil*. **243**: 57-66.

Abedin, M.J., Cottep-Howells, J. and Meharg, A.A. (2002b). Arsenic uptake and accumulation in rice (Oryza sativa L.) irrigated with contaminated water. *Plant Soil*. **240**: 311-319.

Ahmed, K.M. (2000). Groundwater arsenic contamination in Bangladesh: An overview. In: Bhattacharya, P. and Welch, A. H. (Eds.). Arsenic in groundwater of sedimentary aquifers. 31st International geological congress, Rio de Janerio, Brazil. pp. 3-11.

Anonymous. (1987a). Evaluation of exotic potato varieties in their first, second and third generation. Annual Report, TCRC, BARI, Joydehpur, Gazipur, Bangladesh. pp. 1-20.

Anonymous. (1988a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (1988b). Land Resources Appraisal of Bangladesh for Agricultural Development. Report No. 2. Agroecological Regions of Bangladesh, UNDP and FAO. pp. 472-496.

Anonymous. (1988c). Evaluation of exotic varieties. Annual Report, TCRC, BARI, Joydehpur, Gazipur, Bangladesh. pp. 1-39.

Anonymous. (2004). Annual Internal Review for 2000-2001. Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur- 1710.

Banerjee, D.M. (2000). Some comments on the source of arsenic in the Bengal Deltaic sediments. In: Bhattacharya, P. and Welch, A. H. (Eds.). Arsenic in groundwater of sedimentary aquifers. 31st International geological congress, Rio de Janerio, Brazil. pp. 15-17.

Bangladesh Bureau of Statistics (BBS), (1996). In: *Statistical year book of Bangladesh*, Bangladesh bureau of statistics, statistics division, ministry of planning, peoples republic of Bangladesh. p.10.

BBS (Bangladesh Bureau of Statistic). (2011). Agricultural Statistics Yearbook-2011.

Carbonell-Barrachina, A., Burlo-Carbonell, F. and Mataix Beneyto, J. (1995). Arsenic uptake, distribution, and accumulation in tomato plants: Effect of arsenite on plant growth and yield. *J. Plant Nutrition*. **18**(6): 1237-1250.

Carbonell-Barrachina, A.A., Arabi, M.A., Delaune, R.D., Gambrell, R.P. and Patrick, W.H.J. (1998). Bioavailability and accumulation of arsenic by wetland vegetation: effects on plant growth and nutrition. *J. Env. Sci. Healing*. **33**: 45-66.

Carbonell-Barrachina, A.A., Burlo, E., Burgos-Hernandez, A., Lopez, E. and Mataix, J. (1997). The influence of arsenic concentration on arsenic accumulation in tomato and bean plants. *Sci. Hort.* **71**: 167-176.

Chakraborti, A.K. and Das, D.K. (1997). Arsenic pollution and its environmental significance. Interacad. pp. 262–276.

Das, D., Samantha, G., Mondal, B.K., Choudhury, T.R., Chanda, C.R., Choudhury, P.P. and Basu, G.K. (1996). Arsenic in ground water in six districts of West Bengal. Environmental Geochemistry and Health. **8**: 5-15.

Davis, C.D., Begonia, G.B., Begonia, M.F.T., and Gray, C.N. (1998). Growth responses of Indian mustard (*Brassica juncea* (L.) Czern) and its phytoextraction of lead from a contaminated soil. Bull. Environ. Contain. Taricol. **61**: 38-43.

Ducsay, L. (2000). The influence of phytotoxic effects of As, Cd, Pb on production of biomas, their accumulation and chlorophyll. Acta III. Int. Conf. Inorganic substances in living environment, SPU, Nitra: 34-38.

Duxbury, J.M.; Mayer, A.B.; Lauren, J.G. and Hassan, N. (2003). Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice. *J. Environ. Sci. Health.* **38**: 61-69.

FAOSTAT. (2011). Statistical Database. Food and Agricultural Organization of United Nations, Rome, Italy.

Farid, A.T.M., Roy, K.C., Hossain, K.M. and Sen, R. (2003). A study of arsenic contaminated irrigation water and its carried over effect on vegetable. In: Fate of arsenic in the environment. Ahmed MF, Ali MA, Adeel Z, eds. Bangladesh University of Engineering and Technology, Dhaka, Bangladesh/The United Nations University, Tokyo, Japan. pp. 113-121.

Farid, A.T.M., Roy, K.C., Hossain, K.M. and Sen, R. (2003). Effect of arsenic contaminated irrigation water on vegetables. *Bangladesh J. Agril. Res.* **28**(4): 457-464.

Fazal, M.A., Kawachi, T. and Ichio, E. (2001). Validity of the latest research findings on causes of groundwater arsenic contamination in Bangladesh. *Water Intl.* **26**(2): 380-389.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for agricultural research. Second Edn. Intl. Rice Res. Inst., John Wiley and Sons. New York. pp. 1-340.

Gulz, P.A. (1999). Arsenakkumulation verschiedener Nutzpflanzen in Nahrlosung. BGS Bulletin 23 Landwirtschaftliche Lehnnittelzentrale LMZ (Hrsg.), Zollikofen.

Heikens, A. (2006). Arsenic Contamination of Irrigation Water, Soil and Crops in Bangladesh: Risk Implications for Sustainable Agriculture and Food Safety in Asia. Food and Agricultural Organization of the United Nations, Regional Office for Asia and the Pacific.

Hopenhayn, C. (2006). Arsenic in drinking water: Impact on human health. *Elements*. **2**: 103-107.

Hossain, M.M., Akhter, M.I., Sattar, M.A., Rashid, M.H. and Ali, M.S. (2003). Maintenance of Promising variety/Genotypes. Annual Res. Reports on tubers crop Improvement, TCRC, BARI, Joydehpur, Gazipur. pp. 13-15.

Hussain, A.E., Khan, A.I. and Kabir, H. (1984). Performance of exotic potato varieties in their first generation in the year 1983-84. Proc. 6th Wrorkshop Potato Res. Workers. PRC. BARI, Joydebpur, Dhaka. pp. 9-13.

Imamul Huq S.M., Bulbul, A., Choudhury, M.S., Alam, S. and Kawai, S. (2005a). Arsenic bioaccumulation in a green algae and its subsequent recycling in soils of Bangladesh. In: Bundschuh, Bhattacharya and Chandrashkharam (eds) Natural Arsenic in Ground Water: Occurrence, Remediation and Management. Taylor and Francis Group London. (ISBN 04 1536 700 X): 119-124.

Imamul Huq, S.M. and Alam, M.D. (2005). A Handbook on Analyses of Soil, Plant and Water. In: Imamul Huq SM, Alam MD, eds. Momin Offset Press, 9 Nilkhet, Babupura, Dhaka-1205, Bangladesh.

Imamul Huq, S.M., Rahman, A., Sultana, S. and Naidu, R. (2003). Extent and severity of arsenic contamination in soils of Bangladesh. In: F. Ahmed, M. A. and Ali, Z. A., (Eds.). Fate of arsenic in the environment. BUET-UNU Int. Symp. Dhaka, Bangladesh. pp. 69-84.

Islam, M.Z., Hossain, M.M., Hossain, A. and Islam, K. (2009). Effect of different soil moisture levels on yield attributes of some high yielding potato varieties. Annual Research Report, August 2009. Agronomy Division, BARI, Gazipur.

Jacobs, L.W., Keeney, D.R. and Walsh, L.M. (1970). Arsenic residue toxicity to vegetable crops grown on Plainfield sand. *Agron. J*. **62**:588-591.

Jarup, L. (1992). Dose-response Relations for Occupational Exposure to Arsenic and Cadmium National Institute for Occupational Health, Sweden.

Juzl, M. and Stefl, M. (2002). The effect of leaf area index on potatoes yield in soils contaminated by some heavy metals. *ROSTLINNA VYTROBA*. **48**(7): 298-306.

Kabata-Pendias, A. and Pendias, H. (1992). Trace element in soil and plants. CRC, 2nd Edition. London, UK.

Karim, R.A., Hossain, S.M., Miah, M.M.H., Nehar, K. and Mubin, M.S.H. (2008). Arsenic and heavy metal concentrations in surface soils and vegetables of Feni district in Bangladesh. *Environ Monit Assess.* **145**:417–425

Khan A.W., Ahmad, S.A., Sayed, M.H.S.U., Hadi, S.A., Faruquee, M.H. Khan, M.H., Jalil, M.A. and Ahmed, R. (1997). Arsenic contaminate on in groundwater and its effect on human health with particular reference to Bangladesh, Journal of Preventive and Social Medicine, 16(1):65–73.

Khan, A.W., Ahmad, S.A., Sayed, M.H.S.U., Hadi, S.A., Khan, M.H., Jalil, M.A., Ahmed, R. and Faruque, M.H. (1998). Arsenic contamination in groundwater and its effect on human health with particular reference to Bangladesh. Abstract: *Int. Conference on As Pollution of GW in Bd*. 8-12 Feb. 1998, p. 109.

Larsen, E.H., Moseholm, L. and Nielsen, M.M. (1992). Atmospheric deposition of trace-elements around point sources and human health risk assessment. 2. Uptake of arsenic and chromium by vegetables grown near a wood preservation factory. *Sci. Environ*. **126** (3): 263-275.

McLaughlin, M.J., Williams, C.M.J., McKay, A., Kirkham, R., Gunton, J., Jackson, K.J., Thompson, R., Dowling, B., Partington, D., Smart, M.K. and Tiller, K.G. (1994). Effect of cultivar on uptake of cadmium by potato tubers. *Australian J. Agril. Res.* **45**: 1483–1495.

Mondal, M.R.I., M.S. Islam, M.A.B. Jalil, M.M Rahman, M.S. Alam and M.H.H. Rahman. 2011. KRISHI PROJUKTI HATBOI (Handbook of Agro-technology), 5th edition. Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh, pp: 307.

Norton, G., Deacon, C., Mestrot, A., Feldmann, J., Jenkins, P., Baskaran, C. and Meharg, A.A. (2013). Arsenic Speciation and Localization in Horticultural Produce Grown in a Historically Impacted Mining Region. *Environ. Sci. Technol.* **47**: 6164−6172.

Onken, B.M. and Hossner, L.R. (1995). Plant and determination of arsenic species in soil solution under flooded conditions. *J. Environ. Qual*. 24: 373.

Rahaman, S., Sinha, A.C., Pati, R. and Mukhopadhyay, D. (2013). Arsenic contamination: a potential hazard to the affected areas of West Bengal, India. *Environ Geochem Health.* **35**:119–132.

Rajib, K., Majumder, A. and Pal, S. (2012). Evaluation of potato cultivars against arsenic accumulation under as arsenic contaminated zone of eastern India. *Potato J.* **39**(1): 62-68.

Santra, S.C., Samal, A.C., Bhattacharya, P., Banerjee, S., Biswas, A. and Majumdar, J. (2013). Arsenic in food chain and community health risk: a study in Gangetic West Bengal. Department of Environmental Science, University of Kalyani, Kalyani, West Bengal- 741 235, India. *Procedia Environ. Sci*.

Sanyal, S.K. and Naser, S.K.T. (2002). Arsenic contamination in groundwater of West Bengal (India). Build up in soil- crop systems. In: Analysis and practice in water resources engineering for disaster mitigation. New age International (P) Publishers, New Delhi. pp.216-222.

Shaibur, M.R., Islam, T. and Kawai, S. (2009a). Response of leafy vegetable Kalmi (Water Spinach; *Ipomoea aquatica* L.) at elevated concentrations of arsenic in hydroponic culture. *Water Air Soil Pollution*. **202**: 289-300.

Shamsuddoha, A.S.M., Bulbul, A. and Imamul Huq, S.M. (2005). Accumulation of arsenic in green Algae and its subsequent transfer to soil-plant system. *Bangladesh J. Microbiol*. **22**(2): 148-151.

Smith, A. H., Lingas, E.O. and Rahman, M. (2000). Contamination of drinking water by arsenic in Bangladesh: a public health emergency. Bull. Of the World Health Organization. **78**(9): 1093-1103.

Sultana, R., Rahman, A., Kibria, K.Q., Islam, M.S. and Haque, M.M. (2012). Effect of Arsenic Contaminated Irrigation Water on Growth, Yield and Nutrient Accumulation of *Vigna radiata. Indian J. Innovations Dev*. **1**(9): 132-140.

Sushant, K.S. and Ghosh, A.K. (2010). Effect of Arsenic on Photosynthesis, Growth and its Accumulation in the Tissues of *Allium cepa* (Onion). *Intl. J. Environ. Eng. Management.* **1**(1): 39-50.

Talukdar, D. (2011). Effect of Arsenic-induced Toxicity on Morphological Traits of *Trigonella foenum-graecum* L. and *Lathyrus sativus* L. During Germination and Early Seedling Growth. *Current Res. J. Biological Sci.* **3**(2): 116-123.

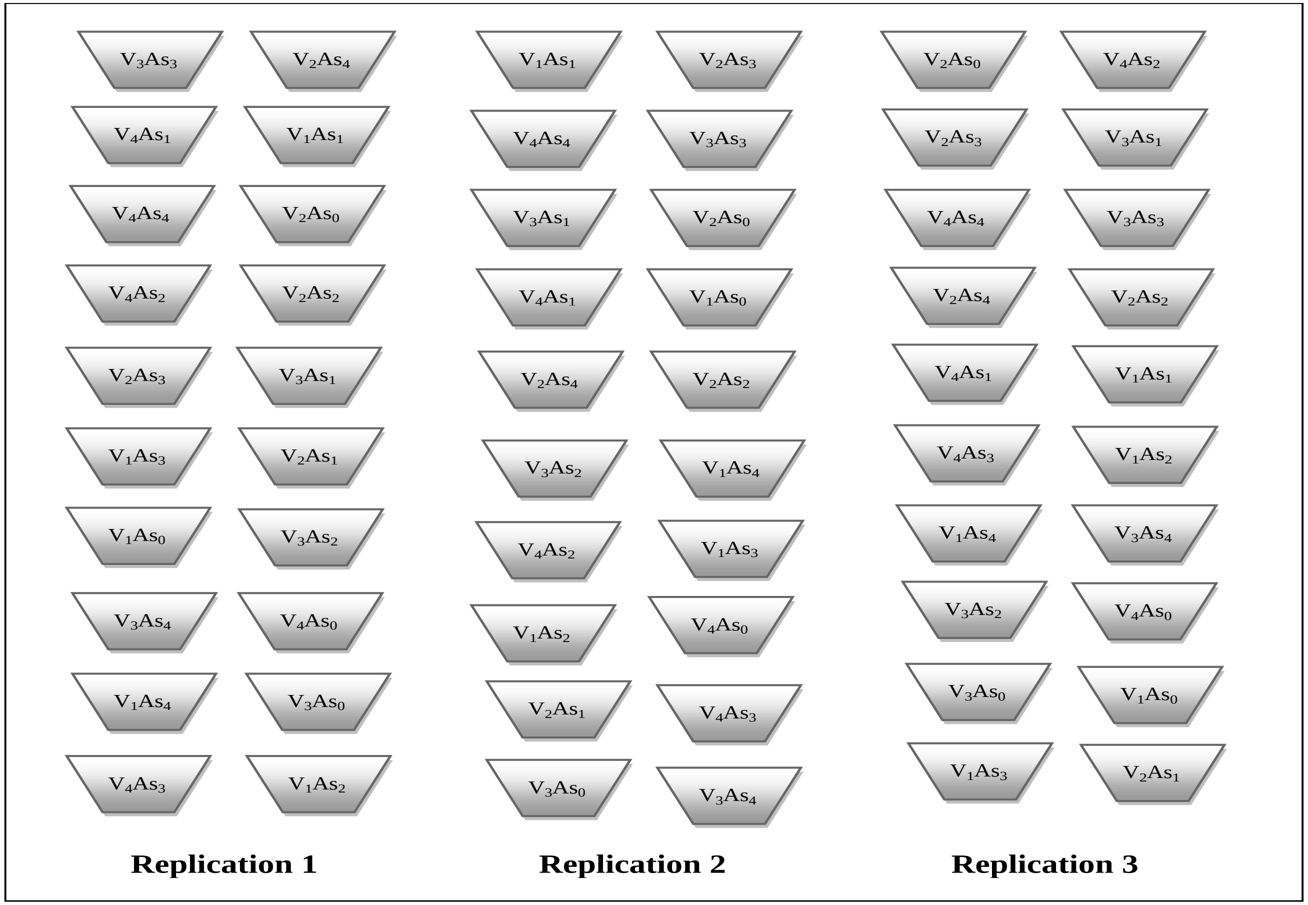
Tu, S. and Ma, LQ. (2003). Interactive effects of pH, arsenic and phosphorus on accumulation of As and P and growth of the arsenic hyperaccumulator *Pteris vittata* L. under hydroponic condition. *J. Environ. Expt. Botany*. **50**: 243-251.

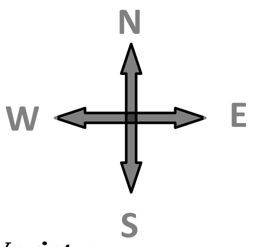
Ullah, S.M. (1998). Arsenic contamination of groundwater and irrigated soils of Bangladesh. In: International conference on arsenic pollution of groundwater in Bangladesh: causes, effects and remedies. DCH, Dhaka, Bangladesh. p. 133.

Williams, P., Geng, C.N., Zhu, Y.G., Hu, Y., and Meharg, A.A. (2006). Arsenate causes differential acute toxicity to two P-deprived genotypes of rice seedlings (*Oryza sativa* L.). *Plant Soil*. 279: 297–306.

Woolson, E.A., J.H. Axley, and P.C. Kearney. (1971b). Correlation between available soil arsenic, estimated by six methods, and response of corn (*Zea mays* L.). *Soil Sci. Soc. Amer. Proc.* **35**:101-105.

Appendix I. Layout of experiment





Variety:
V_1= Cardinal
V_2= Daimant
V_3= Astarix
V_4= Granola

Arsenic:
As_0 – 0 mg As kg^{-1} soil
As_1 – 10 mg As kg^{-1} soil
As_2 – 20 mg As kg^{-1} soil
As_3 – 30 mg As kg^{-1} soil
As_4 – 40 mg As kg^{-1} soil

Appendix II. Analysis of variance of the data on days to emergence

Source of Variation	Degrees of freedom (df)	Mean Square for Days to first emergence
Factor A	3	16.31
Factor B	4	24.64
Interaction (A x B)	12	0.24
Error	38	1.32

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix III. Analysis of variance of the data on plant height at different DAP

Source of Variation	Degrees of freedom (df)	Mean Square for plant height at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Factor A	3	12.3	132.6**	136.2**	143.4**	137.37**
Factor B	4	17.4	225.6**	362.8**	340.6**	311.13**
Interaction (A x B)	12	10.7	4.9	4.1	4.9**	6.01**
Error	38	11.9	3.8	2.6	1.5	1.94

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on number of leaves $plant^{-1}$ at different DAP

Source of Variation	Degrees of freedom (df)	Mean Square for number of leaf at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Factor A	3	245.4**	916.9**	958.2**	940.1**	942.1**
Factor B	4	2.5	580.9**	776.1**	777.8**	769.9**
Interaction (A x B)	12	1.4	0.7	0.8	0.9	0.8
Error	38	29.7	19.9	21.3	20.7	19.8

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on number of stems $hill^{-1}$ at different DAP

Source of Variation	Degrees of freedom (df)	Mean Square for number of stems at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Factor A	3	2.9**	3.2**	4.5**	4.5**	4.5*
Factor B	4	8.7*	13.2**	14.9**	14.9**	14.9**
Interaction (A x B)	12	0.2	0.1	0.1	0.1	0.1
Error	38	0.7	0.4	0.7	0.7	0.7

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on leaf area at different DAP

Source of Variation	Degrees of freedom (df)	Mean Square for leaf area at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Factor A	3	420.1**	888.4**	1298.1**	1328.6**	1300.1**
Factor B	4	280.5**	279.5**	275.9**	242.8**	253.5**
Interaction (A x B)	12	0.9*	2.6*	2.8*	1.4*	3.9*
Error	38	3.1	3.2	3.3	3.5	3.6

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on stem diameter at different DAP

Source of Variation	Degrees of freedom (df)	Mean Square for haulm diameter at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Factor A	3	0.042**	0.109**	0.121**	0.119**	0.105**
Factor B	4	0.041**	0.052**	0.050**	0.051**	0.050**
Interaction (A x B)	12	0.005**	0.000	0.000	0.000	0.000
Error	38	0.002	0.001	0.001	0.001	0.001

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on performance of different potato variety related to yield

Source of Variation	Degrees of freedom (df)	Mean Square for				
		Stem dry matter content (%)	Tuber dry matter content (%)	Tuber peel dry matter content (%)	Number of tuber hill^{-1}	Yield of tuber hill^{-1}
Factor A	3	1.14**	6.22**	1.49**	4.0*	23.71**
Factor B	4	17.9**	120.42**	12.26**	28.77**	74.24**
Interaction (A x B)	12	77.8**	1.68**	0.09*	1.28**	1.06*
Error	38	0.19	0.39	0.06	1.37	0.68

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on performance of different potato variety related to quality

Source of Variation	Degrees of freedom (df)	Mean Square for			
		Grade-A	Grade-B	Grade-C	Grade-D
Factor A	3	522.2**	309.1**	59.3**	6.9**
Factor B	4	25.02**	83.3**	87.4**	22.02**
Interaction (A x B)	12	2.7*	1.7*	3.4**	0.09**
Error	38	2.2	1.4	0.8	0.2

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix X. Analysis of variance of the data on performance of different potato variety related to quality

Source of Variation	Degrees of freedom (df)	Mean Square for			
		Marketable tuber	Non-marketable tuber	Arsenic content of tuber	Arsenic content of tuber peel
Factor A	3	6.9**	6.9**	0.006**	2.291**
Factor B	4	22.02**	22.02**	0.06**	62.503**
Interaction (A x B)	12	0.09**	0.09**	0.001	0.351**
Error	38	0.15	0.15	0.001	0.021

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

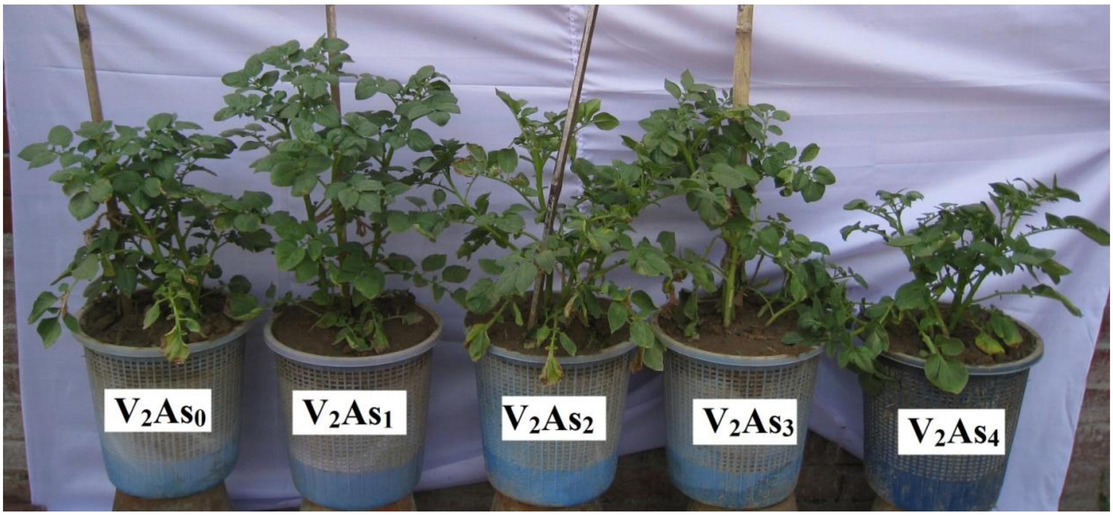
PLATES

Plate 1. Overview of whole experiment

Plate 2. Different treatment combination

Plate 3. Different treatment combination

a. Cardinal variety (V_1)



b. Daimant variety (V_2)

Plate 4. Plant growth variation with different arsnic concentration on soil

a) Cardinal b) Daimant