REMEDEATIVE INFLUENCE OF SAWDUST IN DIFFERENT LEVELS OF ARSENIC PRESENT IN POTATO SOIL

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CERTIFICATE

This is to certify that the thesis entitled ***" REMEDEATIVE INFLUENCE OF SAWDUST IN DIFFERENT LEVELS OF ARSENIC PRESENT IN POTATO SOIL"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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. NOUSAD HOSSAIN,*** *Registration. No.* ***07-02389****, 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

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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The Author

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REMEDEATIVE INFLUENCE OF SAWDUST IN DIFFERENT LEVELS OF ARSENIC PRESENT IN POTATO SOIL

ABSTRACT

A pot experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka from November 2012 to February 2013, to find out the effects of sawdust and Arsenic on potato and evaluation of treatments for the identification of optimum sawdust level for minimizing the toxicity of As in potato tuber grown in As contaminated soil. The experiment included 4 sawdust levels viz., S_0 (control), S_1(10 g kg^{-1} soil), S_2 (50 g kg^{-1} soil), S_3 (100 g kg^{-1} soil) and 4 As levels viz., As_0 (control), As_1(25 mg kg^{-1} soil) As_2 (50 mg kg^{-1} soil), As_3 (75 mg kg^{-1} soil). The result revealed that all growth and yield contributing parameters positively responded with increasing sawdust levels except days to emergence and days to maturity, but quality parameters like tuber peel and flesh increased gradually with the increasing level of this treatment while opposite trend was observed for total soluble solids. The value of specific gravity increased up to S_1 (10 g sawdust kg^{-1} soil) and there after decreased with increasing sawdust levels. As content both peel and flesh decreased with increasing sawdust levels. The soil treated with S_3 (100 g sawdust kg^{-1} soil) reduced 51.44% and 86.41% As accumulation through tuber flesh and peel respectively compared to control (S_0). Yield of potato gradually decreased with increasing of sawdust levels. The effect of As levels were also significant on growth, yield and quality contributing parameters viz., As content of potato peel and flesh, specific gravity of tuber. Yield of potato decreased with increasing As levels. As content of potato tuber flesh and peel gradually increased with increasing the As levels. As_3 (75 mg As kg^{-1} soil) level was found for the maximum accumulation of As in tuber peel and flesh. Among the treatment combinations, though As_1S_1 produced little bit lower yield (430.4 g $plant^{-1}$) compared to that of As_0S_0 (543.6 g) $plant^{-1}$, but potato produced from As_1S_1 accumulated lower amount As (0.15 mg kg^{-1}soil) in potato flesh compared to those of other . Therefore, farmer can produced potato in 25 mg kg^{-1} contaminated soil treated with 10 g sawdust kg^{-1} soil with product contain lower safe content of As in their product.

CHAPTER I

INTRODUCTION

Bangladesh is the world's eighth most populous country with number of major challenges, including poverty, corruption and arsenic toxicity. Now a day’s arsenic toxicity is a crucial issue in Bangladesh and 30 mostly affected districts with 25 million people are at present drinking water contaminated with arsenic at levels above 50 µg L^{-1} and arsenic-affected villages have screened 103,896 villagers and diagnosed 12,195 people with arsenical skin lesions (Chowdhury *et al*., 2000). 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). 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 *et al*., 2005). 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 *et al*., 2003). Major source of As in soil is underground irrigation. Intensive cultivation of cereal (Boro rice, Wheat and Maize), root crop (Potato, Sweet potato, Carrot etc.) and vegetable require high amount of irrigation water (Abedin, 2002). When underground As contaminated water is use as irrigation water As fixes with soil colloid, organic matter and a few amount uptake by plant that is why, soil As the major source for the up taking of As by the crop plants. Total As concentration in soils is increasing day by day with average concentration 35 to 40 mg kg^{-1} and maximum 75 mg kg^{-1} that can reach levels up to more than 1000 mg kg^{-1} (Mukhopadhyay *et al*., 2002). Geochemical sources of As contaminated include As rich parent material as As easily substitutes for Si, Al or Fe in silicate minerals (Bhumbla and Keefer, 1994). Other natural sources of As include volcanic activities, low temperature volatilization and natural weathering of As containing minerals (Wilkie and Hering, 1996). 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} soil) 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.*, 2002). Arsenic accumulation in the plant parts depends on many factors such as plant species, soil type, nutrient supply and pH (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 *et al*., 2005; Shamsuddoha *et al*., 2005; Shaibur *et al*., 2009). 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^{-1}), 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, 2013). 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, 2012). The total production is increasing day by day as such consumption also rapidly increasing in Bangladesh. 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 and or soil on potato production and toxicity in potatoes and its impact on sustainable agriculture. Biosorption technology includes metal removal performance for industrial waste water is economical compare with others (Lee *et al*., 2009). It is a conventional technique for metal remediation. Biosorption uses adsorbents derived from non-living biomass like sawdust, rice husk, egg shell etc. and removes toxic metals from industrial wastewater (Lee *et al*., 2009). The predominant uptake mechanism usually involves unspecific ion exchange reactions. For instance, positively charged groups present in the biomass structure, such as the amino groups, are potential reactive sites to form adsorptive complexes with negatively charged ions such as arsenate, arsenite, chromate, sulfate, or phosphate (Veglio and Beolchini 1997). Some efforts have been made to remove arsenate by biosorption (Hansen *et al*., 2006). However, challenges in developing biosorbents with high uptake and low cost as well as in understanding the biosorption mechanism still remain unexploited.

Objective

Under the mentioned circumstances the present study was undertaken to find out the optimum sawdust level for minimizing the affect of As in potato in As contaminated soil. So the objective of this study were as follow-

i. To study the effect of As and / or sawdust on the growth, yield and quality of the potato.
ii. To find out the optimum sawdust level for the minimizing the affect of As in potato in As contaminated soil.

CHAPTER II

REVIEW OF LITERATURE

2.1 Arsenic effect

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 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.

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 of plant) 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 from 0.032 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 (Mungbean) 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* (mungbean) 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.

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 (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}, 0.200 mg L^{-1}, 0.600 mg L^{-1}, and 0.800 mg 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 0.800 mg 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) and 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.* (2002) 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.* (2002) 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 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, snapbeans, 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 Minimizing toxicity of arsenic by biosorption technology

Sud *et al*. (2008) mentioned that heavy metal remediation of aqueous streams was of special concern due to recalcitrant and persistency of heavy metals in environment. Conventional treatment technologies for the removal of these toxic heavy metals were not economical and further generate huge quantity of toxic chemical sludge. Biosorption was emerging as a potential alternative to the existing conventional technologies for the removal and/or recovery of metal ions from aqueous solutions. The major advantages of biosorption over conventional treatment methods include: low cost, high efficiency, minimization of chemical or biological sludge, regeneration of biosorbents and possibility of metal recovery. Cellulosic agricultural waste materials were an abundant source for significant metal biosorption. The functional groups present in agricultural waste biomass viz., acetamido, alcoholic, carbonyl, phenolic, amido, amino, sulphydryl groups etc. had affinity for heavy metal ions to form metal complexes or chelates. The mechanism of biosorption process includes chemisorptions, complexation, adsorption on surface, diffusion through pores and ion exchange etc. Agricultural waste material being highly efficient, low cost and renewable source of biomass could be exploited for heavy metal remediation. Further these biosorbents could be modified for better efficiency and multiple reuses to enhance their applicability at industrial scale.

Kartal and Imamura (2005) conducted an experiment to evaluate the removal of copper, chromium, and arsenic elements from chromated copper arsenate (CCA)-treated wood via biosorption by chitin and chitosan. Exposing CCA-treated sawdust to various amounts of chitin and chitosan for 1, 5, and 10 days enhanced removal of CCA components compared to remediation by deionized water only. Remediation with a solution containing 2.5 g chitin for 10 days removed 74% copper, 62% chromium, and 63% arsenic from treated sawdust. Remediation of treated sawdust samples using the same amount of chitosan as chitin resulted in 57% copper, 43% chromium, and 30% arsenic removal. The results suggested that chitin and chitosan had a potential to remove copper element from CCA-treated wood. Thus, these more abundant natural amino polysaccharides could be important in the remediation of waste wood treated with the newest formulations of organometallic copper compounds and other water-borne wood preservatives containing copper.

Urik *et al*. (2009) showed that the maximum biosorption capacity of the sawdust modified with ferric oxyhydroxides, evaluated by Langmuir adsorption model, was 9.259 mg g^{-1}. The adsorption capacity suggesting that the prepared chemically modified biosorbent had potential in remediation of As from contaminated soil water.

Shukla *et al*. (2002) observed that sawdust was relatively abundant and inexpensive material was currently being investigated as an adsorbent to remove toxic salts and heavy metals from waste water.

Elizalde-González *et al*. (2008) carried out an experiment in laboratory condition on chemically modified maize cobs waste with enhanced adsorption properties upon methyl orange and arsenic. Adsorption of arsenite by the samples modified with phosphoric acid/ammonia was 11 μg g^{-1}, which corresponded to 98% removal from a 550 μg As L^{-1} solution for an adsorbent dose of 50 mg ml^{-1}. The samples modified by phosphoric acid/urea removed 0.4 μg g^{-1} arsenate from a 300 μg As L^{-1} solution Adsorption of methyl orange, arsenite and arsenate was superior by the chemically modified maize cobs judged against the initial natural sorbent. For comparison, removal by the commercial anion exchanger was 100% for methyl orange, 45% (5 μg g^{-1}) for arsenite and 99% (5 μg g^{-1}) for arsenate.

Vithanage *et al*. (2012) focuses the behaviour of arsenic in plant–soil and plant–water systems, arsenic–plant cell interactions, phytoremediation, and biosorption. Arsenate and arsenite up taken by plants varies in different environment conditions. In biosorption techniques, contaminants could be removed by a biological substrate, as a sorbent, bacteria, fungi, algae, or vascular plants surfaces based on passive binding of arsenic or other contaminants on cell wall surfaces containing special active functional groups. Hence, more efforts are needed on addressing the molecular level behavior of arsenic in plants, kinetics of uptake, and transfer of arsenic in plants with flowing waters, remobilisation through decay, possible methylation, and volatilisation.

Lim *et al.* (2009) carried out an experiment on evaluation of the feasibility of oyster-shell and eggshell wastes for stabilization of arsenic-contaminated soil. Objectives of research were evaluation of the feasibility of using different bioabsorbent like oyster-shell and eggshell wastes for the stabilization of arsenic-contaminated soil. Artificial As (V) contaminated soil was mixed with 0~5% oyster-shell and eggshell wastes and each sample was incubated for 30 days in a controlled environment. The efficiency of each treatment was evaluated using various single extractants (1 N HCl, 0.1 N NaOH and 0.5 N H_2SO_4). The concentration of As (V) was reduced by 10 % upon a 5 % oyster-shell or eggshell waste treatments based on the Korea Standard Test method (1 N HCl extraction). Analogous trends were observed in the 0.1 N NaOH or 0.5 N H_2SO_4 extractions. In addition, the oyster-shell and eggshell waste treatments increased the pH of each soil from 6.54 (control) to 7.62~7.94. The exchangeable Ca in each soil also sharply increased from 6.87 c mol (+) kg^{-1} (control) to 12.77~20.18 c mol (+) kg^{-1}. Further research was needed to increase the effectiveness of the oyster-shell and eggshell waste for the stabilization of As (V) in the contaminated soil.

Honggichan *et al.* (2009) conducted a research to evaluate the feasibility of waste chestnut as a new biosorbent to recover platinum from industrial waste water. This study was part of a larger project to develop precious metal recovery process using bisorption technology (agricultural by-product) produced in Korea. Batch-type adsorption experiment was carried out to determine platinum adsorption in an aqueous solution by chestnut shell. Result showed that Freundlich isotherms adequately described platinum adsorption with R^2 of 0.930. The mechanism of platinum adsorption by chestnut shell was evaluated by characterizing surface properties, functional group and chemical composition of chestnut shell using SEM-EDS and FT-IR analyses.

Lee *et al*. (2013) carried out a research on heavy metal immobilization in soil near abandoned mines using eggshell waste and rapeseed residue. Heavy metal contamination of agricultural soils had received great concern due to potential risk to human health. Cadmium and Pb were largely released from abandoned or closed mines in Korea, resulting in soil contamination. The objective of this study was to evaluate the effects of eggshell waste in combination with the conventional nitrogen, phosphorous, and potassium fertilizer (also known as NPK fertilizer) or the rapeseed residue on immobilization of Cd and Pb in the rice paddy soil. Cadmium and Pb extractabilities were tested using two methods of (1) the toxicity characteristics leaching procedure (TCLP) and (2) the 0.1 M HCl extraction. With 5 % eggshell addition, the values of soil pH were increased from 6.33 and 6.51 to 8.15 and 8.04 in combination with NPK fertilizer and rapeseed residue, respectively, compared to no eggshell addition. The increase in soil pH may contribute to heavy metal immobilization by altering heavy metals into more stable in soils. Concentrations of TCLP-extracted Cd and Pb were reduced by up to 67.9 and 93.2 % by addition of 5 % eggshell compared to control. For 0.1 M HCl extraction method, the concentration of 0.1 M HCl-Cd in soils treated with NPK fertilizer and rapeseed residue was significantly reduced by up to 34.01 and 46.1 %, respectively, with 5 % eggshell addition compared to control. As decrease in acid phosphatase activity and increase in alkaline phosphatase activity at high soil pH were also observed. Combined application of eggshell waste and rapeseed residue can be cost-effective and beneficial way to remediate the soil contaminated with heavy metals.

Lee *et al*. (2012) conducted an experiment to evaluate the adsorption efficiency of chestnut shell (CS), oak derived sawdust (Q) and chemically modified sawdust (SH-Q) for removing lead (Pb) in perimental data. The maximum adsorption capacities (qm) as determined by the aqueous solution. Langmuir isothermal adsorption model was well fitted to the ex Langmuir equation at pH 5 were 31.3 mg g^{-1}, 8.9 mg g^{-1} and 27.0 mg g^{-1} for CS, Q and

SH-Q, respectively. After equilibrium, the pH of aqueous solution was decreased from the initial pH 5.1 to pH 4.5 in CS and Q treatments.

Moon *et al*. (2011) mentioned that natural oyster shells (NOS) and calcined oyster shells (COS) were used to immobilize arsenic (As) from contaminated mine tailings. In addition, a blend of Portland cement (PC) / cement kiln dust (CKD) was used as a stabilizing agent. The Korean Standard Test (KST) method (1 N HCl extraction) was used to evaluate the effectiveness of the treatment. The experimental results showed that COS effectively immobilized As in treated mine tailings. Specifically, an As concentration less than 1 mg L^{-1} was obtained following COS treatment at 25 and 30 wt %. However, all the samples subjected to NOS treatments failed the Korean warning standard of 1.2 mg L^{-1} after 28 days of curing. All of the COS-PC treatments were successful meeting the Korean warning standard after 7 days of curing. However, the PC-only treatment failed to meet the Korean warning standard. Similarly, the CKD-only treatment was failed to meet the Korean warning standard after 7 days of curing. The COS-CKD treatment showed that when the COS content was greater than 20 wt %, less than 1 mg L^{-1} of As leach ability was obtained. Scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM–EDX) showed needle-like and torpedo-like Ca–As phases in the COS-treated samples suggesting that As was strongly associated with Ca and O. X-ray absorption near edge structure (XANES) analyses confirmed that As (V) was prevalent in the tailings and that there were no changes in As speciation following NOS or COS treatment.

Lee *et al*. (2009) conducted a research on adsorption characteristics of heavy metal ions onto chemically modified rice husk and sawdust from aqueous solutions. Biosorption used adsorbents derived from non-living biomass and removes toxic metals from industrial wastewater. The objective of this research was to evaluate the potential of low cost biosorbents to remove heavy metal ions (Cd, Cu, Pb and Zn) from aqueous solutions using chemically modified rice husk and saw dust (Pseudotsuga menziesi, Quercus, Populus). Batch-type adsorption experiments were carried out using rice husk and saw dust treated with NaOH and / or tartaric acid in artificial waste water (100 mg metal / L). The experimental results showed that the adsorption specificity of each biosorbent was Pb > Cu > Cd > Zn irrespective of the types of biosorbents. The adsorption capacity of Pb and Cu on to NaOH-treated sawdust was increased 2~3 times compared to the untreated one. In addition, the tartaric acid treatment increased the adsorption capacity of rice husk for Zn and Cd approximately 5~10 fold compared to the untreated one. Surface conditions and changes in functional groups by chemical modification of each biosorbent were confirmed by SEM and FT-IR. Overall, the results show that chemical modification increases the metal removal capacity of rice bran and sawdust.

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, 2012 to February, 2013.

3.1 Site description

3.1.1 Geographical location

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

3.1.2 Agro-Ecological Region

The experimental site belongs to the Agro-ecological zone of " Modhupur Tract", AEZ-28 (Anon., 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., 1988).

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. Sawdust level (Bioadsorbent): 4

1. S_0 – 0 g Sawdust kg^{-1} soil
2. S_1 – 10 g Sawdust kg^{-1} soil
3. S_2 – 50 g Sawdust kg^{-1} soil
4. S_3 – 100 g Sawdust kg^{-1} soil

B. Arsenic levels: 4

1. As_0 – 0 mg As kg^{-1} soil
2. As_1 – 25 mg As kg^{-1} soil
3. As_2 – 50 mg As kg^{-1} soil
4. As_3 – 75 mg As kg^{-1} soil

Treatment combinations were as:

As_0S_0, As_1S_0, As_2S_0, As_3S_0, As_0S_1, As_1S_1, As_2S_1, As_3S_1, As_0S_2, As_1S_2, As_2S_2, As_3S_2, As_0S_3, As_1S_3, As_2S_3 and As_3S_3.

3.2.2 Experimental design

Experiment was provoked in 2 factors Completely Randomized Design (CRD) for Factor A and Factor B with three replications thus comprised 48 baskets. 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 Cardinal varieties of potato

3.4 Crop management

3.4.1 Seed collection

Seed potato (certified 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 3th November 2012.

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: Mondal *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 and Sawdust treatment

For the As treatment of soil, sodium meta arsenate (Na_2HAsO_4,7 H_2O) was used as the source of As. As application was done by adding 0 mg kg^{-1} soil, 25 mg kg^{-1} soil, 50 mg kg^{-1} soil and 75 mg kg^{-1} soil sodium meta arsenate into soil of baskets according to treatment. Sawdust was collected from Mirpur Sawmill, Dhaka. Application of sawdust treatment was done by adding 0g kg^{-1} soil, 10 g kg^{-1} soil, 50 g kg^{-1} soil, 100 g kg^{-1} soil into soil of baskets according to treatment.

3.4.6 Tagging

Tagging was done by application of Arsenic on 5th November 2012 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 2012.

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 bacterial wilt which did not hampered on plant growth.

3.4.8.5 Haulm cutting

Haulm cutting was done at 11th 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 18th February at 7 days after haulm cutting. The potatoes of each basket were separately harvested, bagged and tagged and brought to the laboratory. The potato yield basket^{-1} was determined in gram. The basket was set at 60 cm × 25 cm spacing, considering 66666 baskets were accommodated in 1 ha area.

3.4.9 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 (Visual observation)
    ii. Plant height (at 30, 45, 60 and 75 DAP) (cm)
    iii. Number of leaves plant^{-1}(at 30, 45, 60 and 75 DAP)
    iv. Number of stems hill^{-1}(at 30, 45, 60 and 75 DAP)
    v. Leaf area plant^{-1} (at 30, 45, 60 and 75 DAP) (cm^2)
    vi. Chlorophyll content in leaf (%) at 75 DAP
    vii. Stem diameter (cm) (at 30, 45, 60 and 75 DAP)
    viii. Stem dry matter content (%)
    ix. Days to maturity (Visual observation)

B. Yield and yield components

i. Number of tubers hill^{-1}
ii. Yield of tuber plant^{-1} (g)
iii. Marketable and non-marketable yield (% by weight and number) (g)

C. Quality characters

i. Tuber flesh dry matter content (%)
ii. Tuber peel dry matter content (%)
iii. Total soluble solids content of tuber (%)
iv. Specific gravity of tuber
v. Arsenic content of tuber peel (mg kg^{-1})
vi. Arsenic content of tuber flesh (mg kg^{-1})

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 and 75 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 and 75 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 and 75 DAP. Stem numbers hill^{-1} was recorded by counting all stem from each basket.

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

Leaf area plant^{-1} was measured at 30, 45, 60 and 75 DAP 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. Chlorophyll content in leaf (%)

Chlorophyll content in leaf (%) was measured by non destructive method using chlorophyll meter SPAD-502Plus (KONICA MINOLTA SENSING INC, Japan). Mature leaf (from 4th node) were measured all time and expressed in percentage (%). Five mature plant of each pot were measured and then average it after that mean was calculated.

vii. Stem diameter (cm)

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

viii. 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:

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

ix. Days to maturity

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

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

Total soluble solids content of tuber

Total soluble solids was measured in brix percentage by reflector meter. Three tuber samples were taken from each treatment to determine total soluble solids then calculate average value from three sample data.

Specific gravity of tuber

Fresh weight of tuber was taken first. Then the samples of tuber were sunk in fully water fill beaker. The tuber removes equal volume of the water. The removed water weight was taken and specific gravity of tuber was calculated with the following formula:

$$\text{Specific gravity} = \frac{\text{Weight of fresh tuber}}{\text{Weight of equal volume of water removed by tuber}}$$

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 Least Significant Difference Test (LSD) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

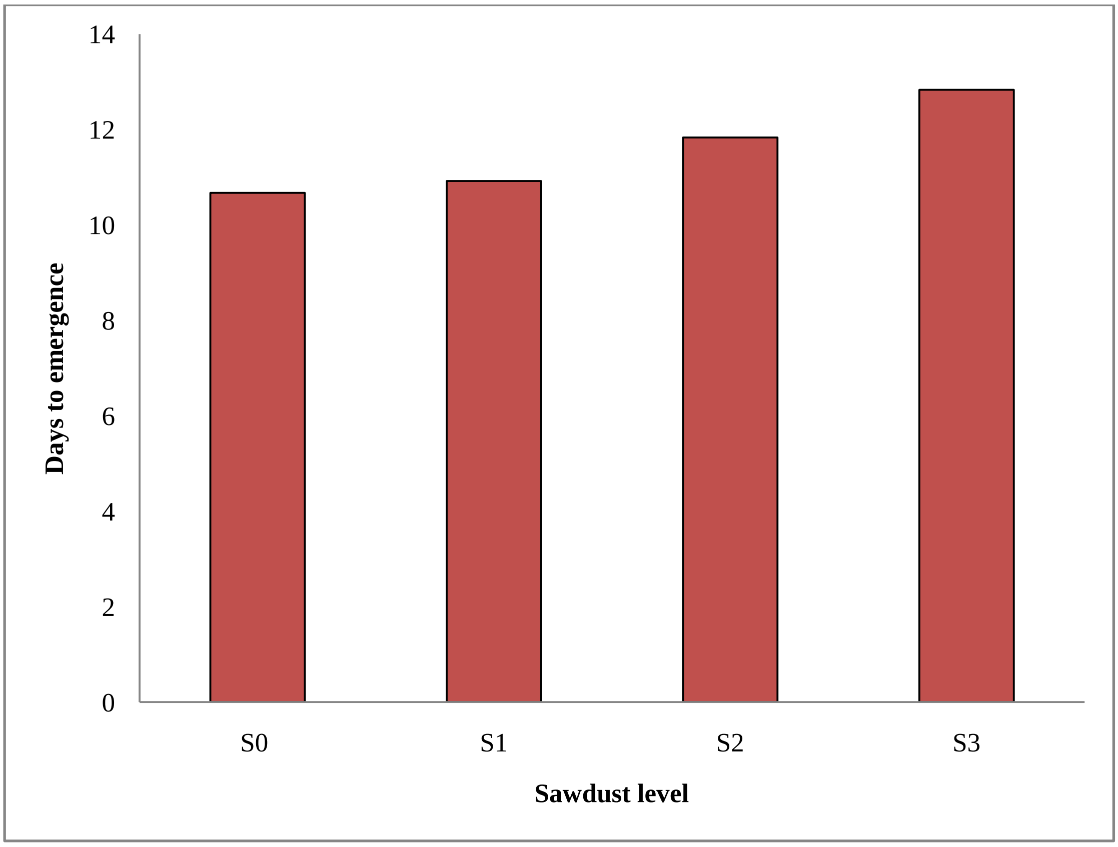
The research work was accomplished to investigate the effect of As on growth, yield and quality of potato in Bangladesh. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The analysis of variance of data respect of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

4.1 Days to emergence (Visual observation)

Days to emergence was significantly ($P \leq 0.05$) affected by sawdust levels (Appendix III) . Figure 1 showed that days to emergence increased with increasing sawdust levels. The minimum duration (10.67 days) required in S_0 treatment which was statistically similar to S_1 (10.92 days) and S_2 (11.83 days) and delayed in S_3 (12.83 days) treatment which was statistically similliar to S_2 (11.83 days).

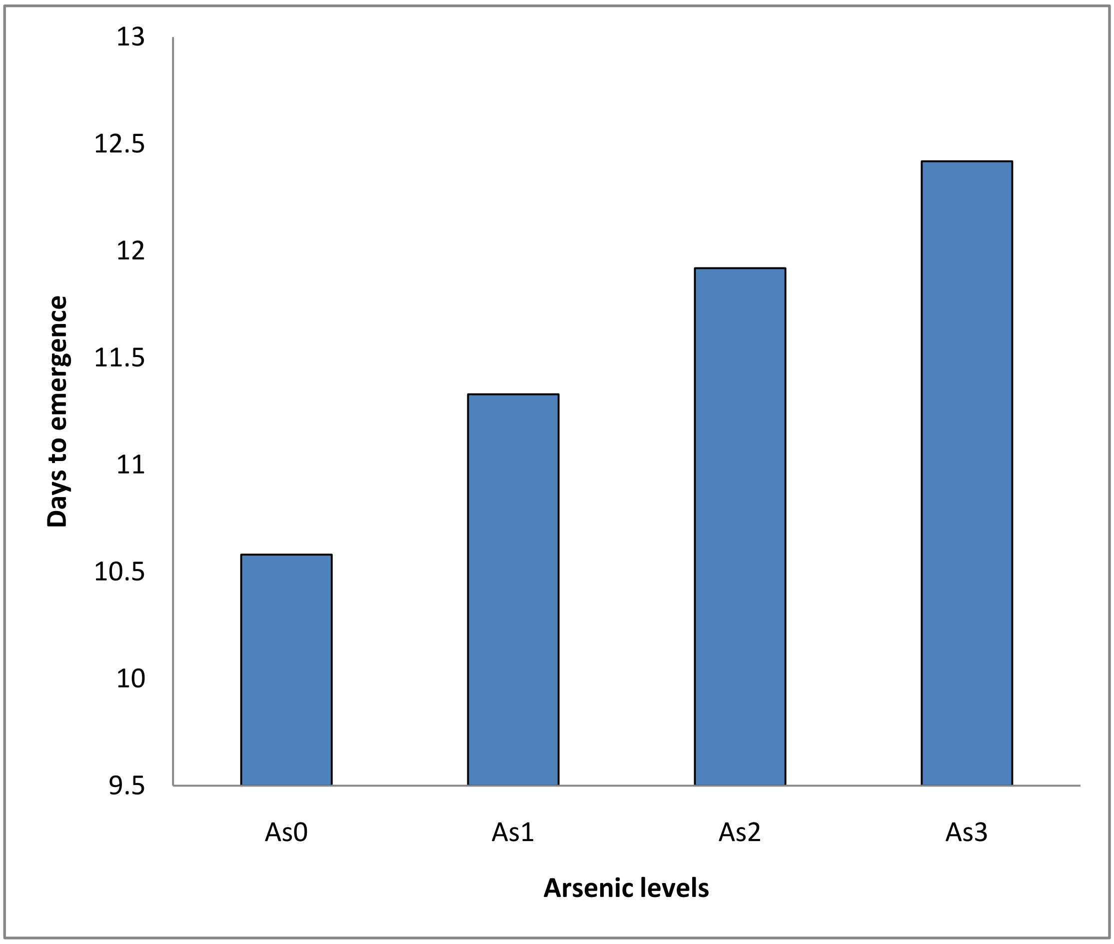
Days to emergence was also significantly ($P \leq 0.05$) affected by As levels (Appendix II). Figure 2 showed that days to emergence increased with increasing As levels. The minimum period (10.58 days) required in As_0 treatment which was statistically similar to As_1 (11.33 days) and As_2 (11.92 days) treatment and delayed (12.42 days) in As_3 (75 mg As kg^{-1} soil) . 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 in case 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.*, 2002).

Combined effects of sawdust and As levels significantly ($P \leq 0.05$) influenced by days taken to emergence of potato tubers (Appendix III). The treatment combination S_0As_0 required minimum days (10) for emergence which was statistically similar to As_1S_0 (10 days), As_2S_0 (11.33 days), As_3S_0 (12.33days), As_3S_0 (10 days), As_0S_1 (10 days), As_1S_1 (10 days), As_2S_1 (11 days), As_3S_1 (11.67 days), As_0S_2 (11 days), As_1S_2 (11 days), As_2S_2 (11.33 days), As_0S_3 (12.33 days) and As_1S_3 (12.67 days) whereas the maximum (14.33 days) required for As_3S_3 (Figure 3).



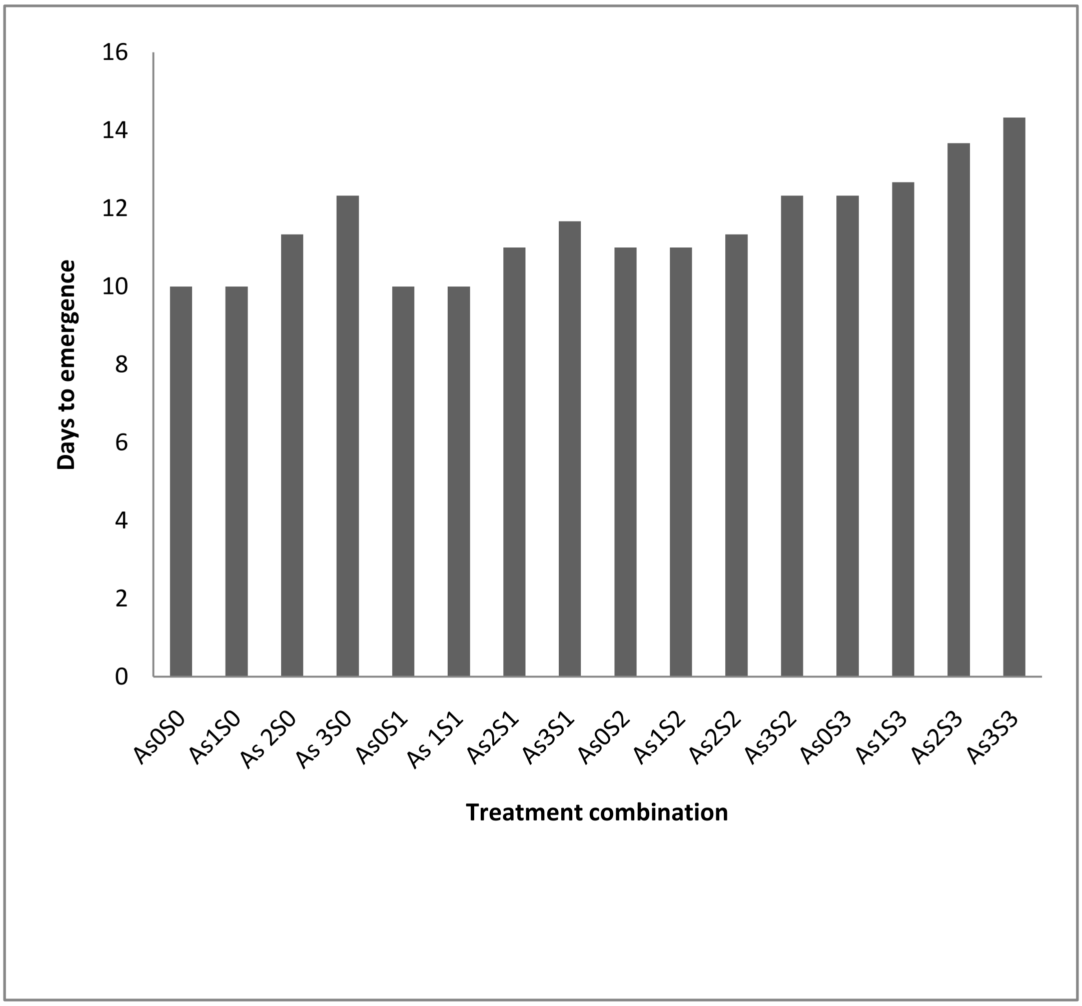
[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 1. Effect of sawdust levels on days to emergence [LSD value: 1.41]



[As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

Figure 2. Effect of Arsenic levels on days to emergence of potato
[LSD value: 1.48]



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil and As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

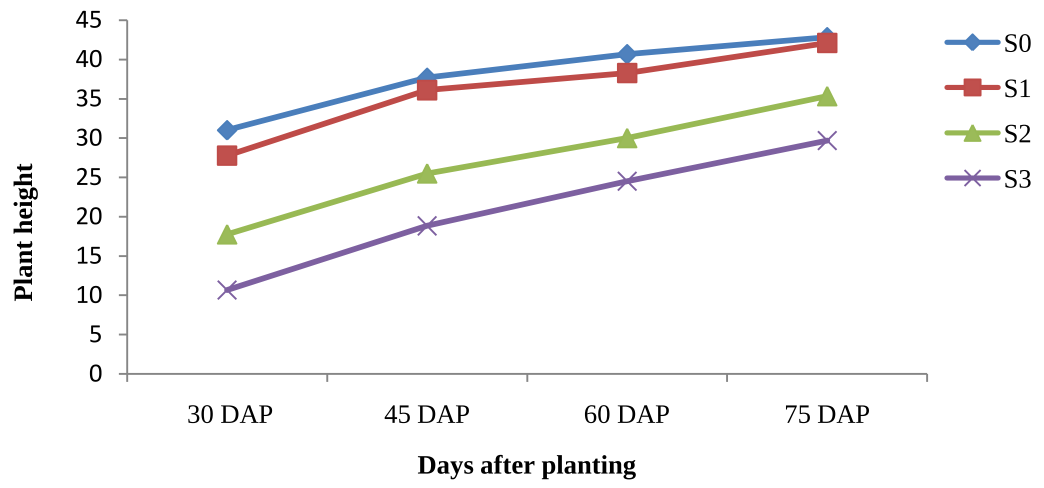
Figure 3. Combined effects of sawdust and different As levels on days to emergence of potato [LSD value: 1.42]

4.2 Plant height (cm)

Plant height was significantly ($P \leq 0.01$) affected by different sawdust levels at 30, 45, 60 and 75 DAP (Appendix IV). Figure 4 showed that plant height gradually decreased with increasing sawdust levels. The tallest plant was recorded in control S_0 (42.83 cm) which was statistically similar to As_1 (42.08 cm) while the shortest plant was scored in S_3 (10.67 cm) at 75 DAP.

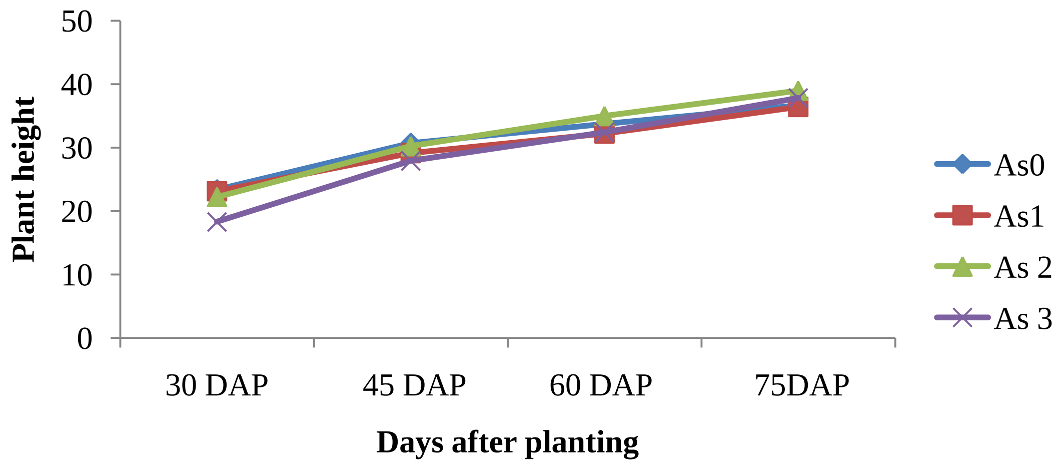
Plant height of potato varieties exposed statistically non-significant among different As levels at 30, 45, 60, and 75 DAP (Appendix IV). Numerically the tallest plant in As_2 (39.00 cm) was recorded while the shortest plant was scored in As_1 (36.42 cm), at harvesting stage (Figure 5). Hussain (2012) 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 that indicates 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.*, 2002).

Combined effect of different sawdust and As levels on potato in terms of plant height also exposed significant ($P \leq 0.05$) variation (Appendix III). Plant height of potato varieties observed statistically significant among treatments at 30, 45, 60 and 75 DAP (Fig. 6). The tallest plant was observed under As_3S_0 (47.33 cm) which was statistically similar to As_2S_0 (47 cm), As_0S_1 (40 cm), As_1S_1 (43 cm), As_2S_1 (41.67 cm) and As_3S_1 (43.67 cm) while the shortest plant was recorded from As_3S_3 (27 cm).



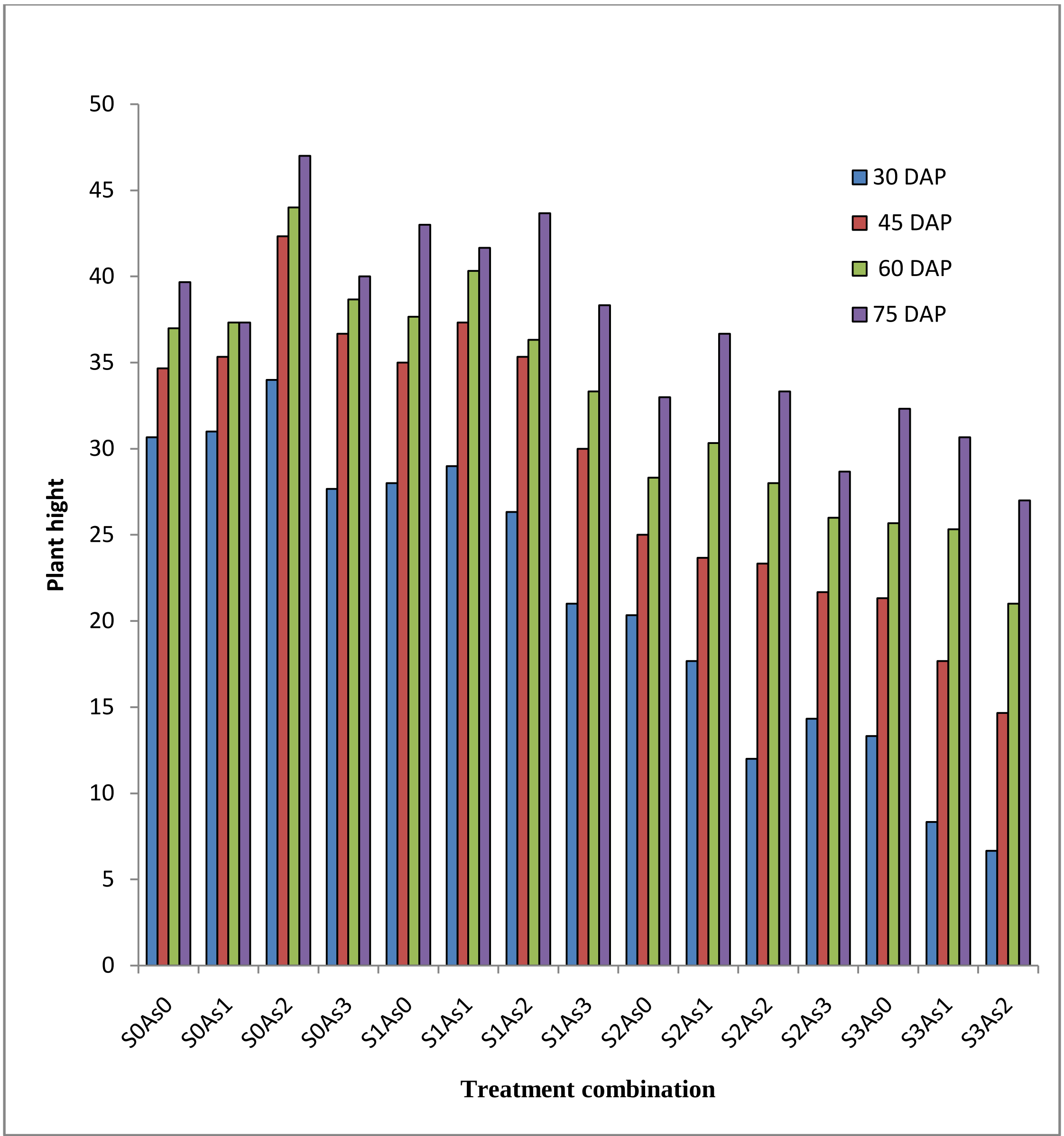
[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 4. Effect of sawdust levels on plant height of potato at different days after planting (DAP) [LSD value 2.57, 3.10, 3.52 and 3.80 at 30, 45, 60 and 75 DAP, respectively]



[As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

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



S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil As_0, Control; As_1, 25mg As kg^{-1} soil; As^2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil,]

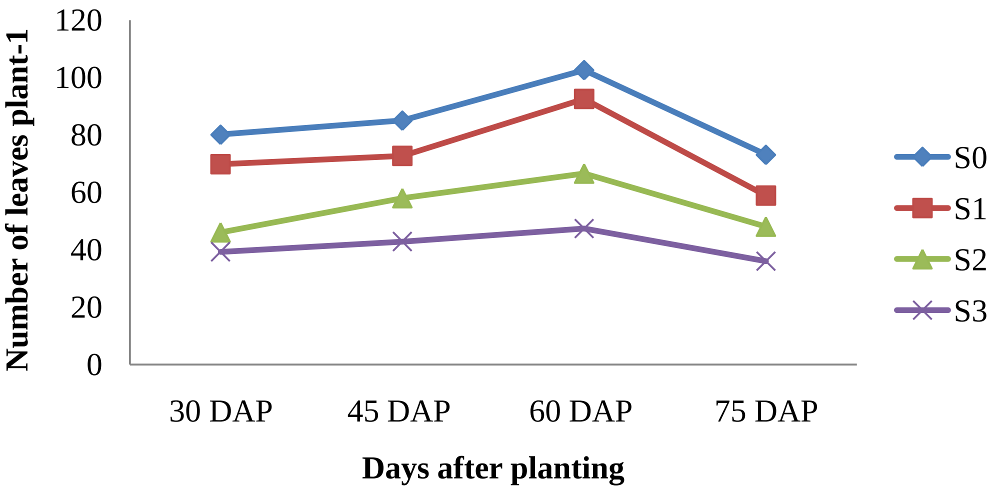
Fig 6. Combined effects of sawdust and As levels on plant height of potato at different days after planting (DAP) [LSD value 5.149, 6.2, 7.052 and 7.618at 30, 45, 60 and 75 DAP, respectively]

4.3 Number of leaves plant^{-1}

Leaves number plant^{-1} of potato exposed statistically significant ($P \leq 0.01$) among different sawdust levels at 30, 45, 60 and 75 DAP (Appendix V). Number of leaves plant^{-1} increased with increasing the sawdust levels in soil up to 60 DAP and thereafter decreased with advancing the growing period. Leaves number plant^{-1} was maximum at 60 DAP after then it decreased at 75 DAP due to early leaves senescence. The maximum number of leaves was recorded in S_0 (102.6) treatment at 60 DAP whereas the minimum was recorded in S_3 (39.25) treatment at 30 DAP (Figure 7).

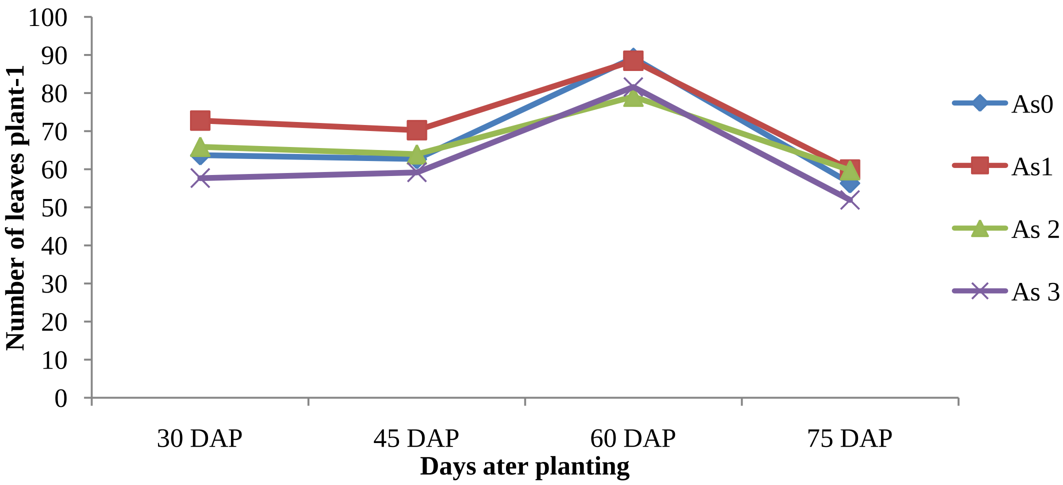
Leaves number plant^{-1} exposed statistically non-significant among different As levels at 30, 45, 60 and 75 DAP (Appendix V). Numerically maximum number leaves plant^{-1} was recorded in As_2 (72.75), As_0 (70.25), As_2 (89.25) and As_2 (59.92) As levels at 30, 45, 60 and 75 DAP respectively where the minimum was recorded in As_3 at 30 (57.63), 45 (59.17), 60 (81.58) and 75 (51.92) DAP, respectively (Figure 8).

Combined effects of sawdust and As levels in terms of leaf number plant^{-1} also exposed significant variation among treatment combinations at 30, 45, 60 and 75 DAP (Appendix V). The maximum number of leave plant^{-1} was recorded from As_1S_0 (111.7) which was statistically similar to As_0S_0 (106.0), As_2S_0 (105.0) and As_3S_0 (97.33) while the minimum was recorded from As_3S_3 (24.67) treatment combination at 30 DAP. Leaf number plant^{-1} at 75 DAP was also significant among treatment combination here the maximum number of leaves plant^{-1} was recorded in As_3S_0 (92.67) which was statistically similar to As_0S_0 (84.33), As_1S_0 (82.00) and As_2S_0 (88.00) whereas, the minimum recorded in As_3S_3 (28.0) treatment combination at 75 DAP (Table 1)



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 7. Effect of sawdust on number of leaves plant^{-1} of potato at different days after planting (DAP) [LSD value = 12.3, 10.66, 10.73 and 9.29 at 30, 45, 60 and 75 DAP, respectively]



[As_0, control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

Figure 8. Effect of As levels on number of leaves plant^{-1} of potato at different days after planting (DAP)

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

Treatment	Number of leaves plant^{-1} at different days after planting			
	30	45	60	75
S_0As_0	106.0 ab	151.7 a	89.67 a	84.33 a
S_0As_1	111.7 a	143.3 ab	77.00 a-c	82.00 ab
S_0As_2	105.0 ab	127.7 b	77.33 ab	92.67 a
S_0As_3	97.33 ab	131.7 ab	81.67 a	88.00 ab
S_1As_0	71.67 cd	86.33 c-e	59.00 b-f	57.33 cd
S_1As_1	82.00 bc	93.67 cd	82.67 a	70.00 bc
S_1As_2	60.67 c-e	76.67 de	74.33 a-d	48.33 de
S_1As_3	64.67 c-e	105.3 c	66.67 a-e	47.67 de
S_2As_0	32.67 fg	70.67 ef	55.67 c-f	44.67 d-f
S_2As_1	50.33 d-f	71.67 ef	67.00 a-e	48.00 de
S_2As_2	57.00 d-f	71.00 ef	59.67 b-f	55.33 cd
S_2As_3	44.00 e-g	52.67 fg	49.33 ef	44.00 d-f
S_3As_0	44.33 e-g	48.33 g	51.67 ef	33.67 ef
S_3As_1	47.00 eg	45.33 g	54.33 d-f	39.67 d-f
S_3As_2	41.00 e-g	41.00 g	44.33 f	42.67 d-f
S_3As_3	24.67 g	36.67 g	39.00	28.00 f
LSD Value	24.61	21.31	21.45	18.6
CV (%)	4.15	4.8	5.83	4.67
Level of significance	*	*	*	*

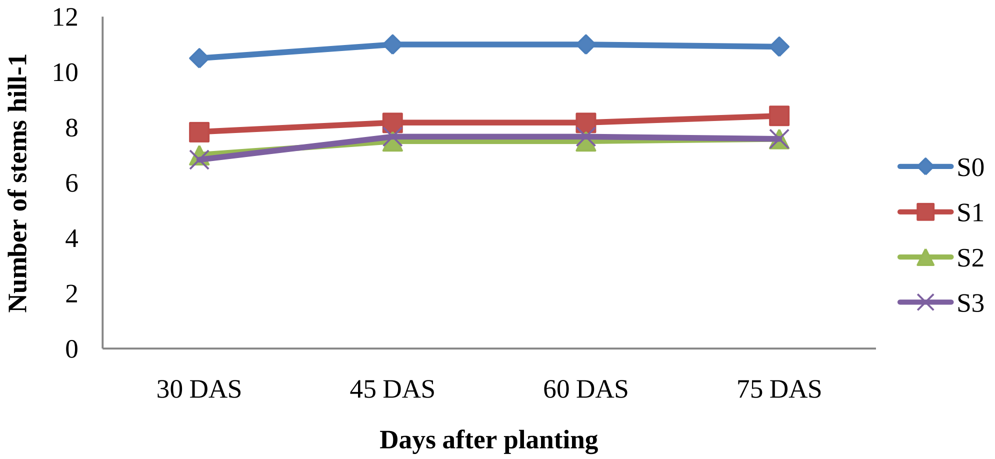
As_0, control; As_1, 25mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and
S_0, control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil
* Indicates 5% level of significance
In a column means having similar letter (s) are statistically 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} of potato showed statistically significant among different sawdust levels (S_0, S_1, S_2 and S_3) at 30, 45, 60 and 75 DAP (Appendix VI). Figure 9 showed that stem numbers hill^{-1} decreased with increasing sawdust levels. The maximum number of stems hill^{-1} was recorded at 30 (10.50), 45(11.00), 60 (11.00) and 75 (10.92) DAP in S_0 respectively while the minimum number of stems hill^{-1} was recorded at 30 (6.833), 45(6.833), 60 (7.500) and 75 (7.583) DAP in S_3, S_2, S_2 and S_2, respectively (Figure 9).

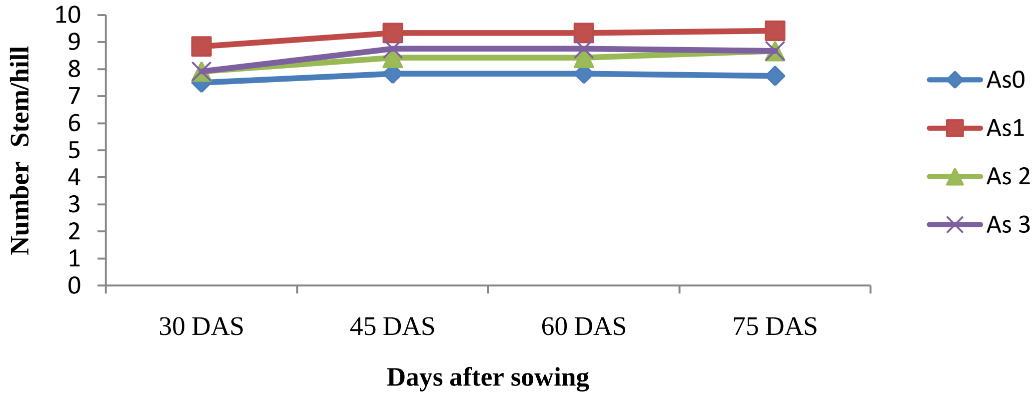
Stem numbers hill^{-1} of potato exposed statistically non-significant among different As levels (As_0, As_1, As_2 and As_3) at 30, 45, 60 and 75 DAP (Appendix V). Numerically the maximum number of stems hill^{-1} was recorded at 30 (8.83), 45 (9.33), 60 (9.33) and 75 (9.41) DAP when treated with As_1, whereas, the minimum was recorded at 30 (7.50), 45 (7.83), 60 (7.83) and 75(7.75) DAP in As_0 (Figure 10). Hussain (2012) showed that stems plant^{-1} increase up to 10 mg As kg^{-1} soil then decrease with increasing of arsenic level.

Combined effects of different sawdust and As levels on potato in terms of stem numbers hill^{-1} also exposed significant variation at 30, 45, 60 and 75 DAP (Appendix V). The maximum stem number hill^{-1} was recorded in As_0S_0 (11.67) which was statistically similar to As_1S_0 (11.33), As_2S_0 (10.67), As_3S_0 (10.33), As_1S_1 (9.33), As_3S_1 (9.33), As_1S_2 (9.00) and As_2S_2 (9.333), whereas, the minimum was recorded from As_0S_2 (4.66) treatment combination at 30 DAP (Table 2).



[S_0, control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 9. Effect of sawdust level on number of stems plant^{-1} of potato at different days after planting (DAP) [LSD value = 1.61, 3.54, 1.77 and 1.77 at 30, 45, 60, 75 and 90 DAP, respectively]



[As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

Figure 10. Effect of Arsenic levels on number of stem of potato at different days after planting (DAP)

Table 2. Combined effect of Sawdust and As levels on number of stems hill^{-1} at different days after planting (DAP) of potato

Treatment	Number of stems hill^{-1} at different days after planting			
	30	45	60	75
S_0As_0	10.67 ab	11.67 a	11.67 a	11.00 ab
S_0As_1	11.00 a	11.33 a	11.33 a	11.33 a
S_0As_2	10.33 a-c	10.67 ab	10.67 ab	10.67 a-c
S_0As_3	10.00 b-d	10.33 a-c	10.33 a-c	10.67 a-c
S_1As_0	7.66 b-f	7.67 b-e	7.66 b-e	7.66 b-f
S_1As_1	8.66 a-e	9.33 a-d	9.33 a-d	9.66 a-e
S_1As_2	6.33 ef	6.33 de	6.33 de	6.33 e-f
S_1As_3	8.66 a-e	9.33 a-d	9.33 a-d	10.0 a-d
S_2As_0	4.66 f	4.67 e	4.66 e	5.00 f
S_2As_1	8.33 a-e	9.00 a-d	9.00 a-d	9.00 a-e
S_2As_2	8.33a-e	9.33a-d	9.33 a-d	9.66 a-e
S_2As_3	6.66 e-f	7.00c-e	7.00 c-e	6.66 d-f
S_3As_0	7.00 d-f	7.33b-e	7.33 b-e	7.33 c-f
S_3As_1	7.33 de	7.66 b-e	7.66 b-e	7.66 b-f
S_3As_2	6.66 ef	7.33 b-e	7.33 b-e	8.00 a-f
S_3As_3	6.33 ef	8.33 a-d	8.33 a-d	7.33 c-f
LSD value	3.54	3.54	3.54	3.54
CV(%)	4.15	4.8	5.83	4.67
Level of significance	*	*	*	*

As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil

* Indicates 5% level of significance respectively

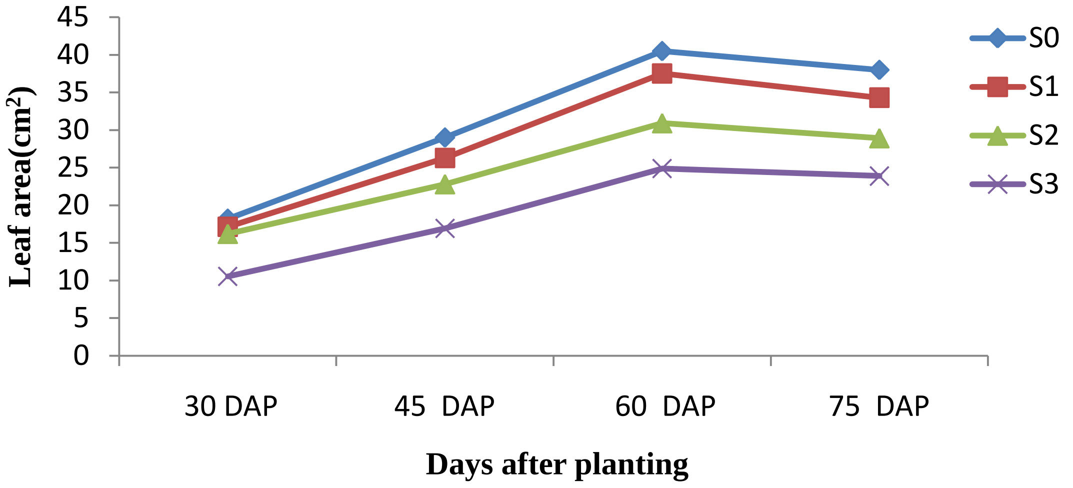
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

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

Leaf area plant^{-1} of potato showed statistically significant among different sawdust levels (S_0, $S_{1,}$ S_2 and S_3) at 30, 45, 60 and 75 DAP (Appendix VII). Figure 11 showed that leaf area decreased with increasing the sawdust levels. The maximum leaf area was recorded at 60 DAP in S_0 (38 cm^2) where as the minimum was recorded at 30 DAP in S_3(10.53 cm^2).

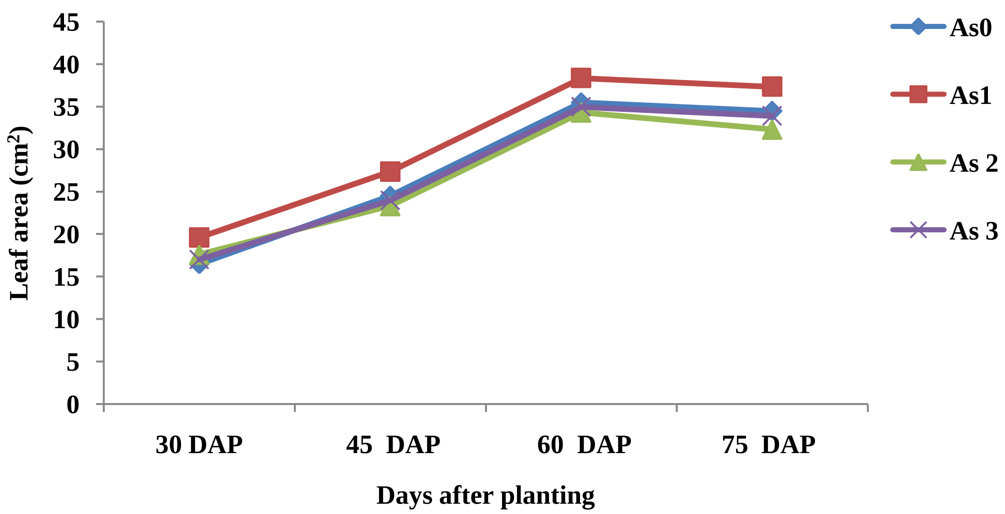
Leaf area plant^{-1} of potato exposed statistically non-significant among different As levels at 30, 45, 60 and 75 DAP (Appendix VII). Numerically the maximum leaf area was recorded at 30 (19.16 cm^2), 45 (27.36 cm^2), 60 (38.36 cm^2) and 75 (42.36 cm^2) DAP, respectively in As_1 whereas, the minimum was recorded at 30 (16.47 cm^2), 45 (23.31cm^2), 60 (40.97 cm^2) and 75 (38.91 cm^2) DAP respectively in As_3 (75 mg As kg^{-1} soil) (Figure 12). Juzl and Stefe (2002) reported that leaf area index of potato plants were significantly decreased with increasing levels of As in irrigated water and soil. Hussain (2012) reported that the leaf area slightly increased up to treated with 10 mg As kg^{-1} soil and thereafter decreased with increasing the levels of As. Present study showed that leaf area plant^{-1} had no significant variation up to treated with 30 mg to 75 mg As kg^{-1} soil.

Combined effect of different sawdust and As levels in terms of leaf area plant^{-1} also exposed significant variation among treatments at 30, 45, 60 and 75 DAP (Appendix VII). The maximum leaf area plant^{-1} at 75 DAP was recorded in As_1S_1 (57.69 cm^2) which was statistically similar to As_0S_0 (54.38 cm^2) and As_2S_0 (49.76 cm^2) whereas the minimum was recorded from As_2S_3 (7.24 cm^2) at 30 DAP (Table 3).



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil**]**

Figure11. Effects of sawdust on the leaf area plant^{-1} at different days after planting (DAP) [LSD value = 4.35, 4.54, 4.31and 4.45 at 30, 45, 60 and 75 DAP, respectively]



[As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

Figure12. Effect of As levels on leaf area plant^{-1}at different days after planting (DAP)

Table 3. Combined effects of sawdust and As levels on leaf area (cm^2) at different days after planting (DAP)

Treatment	Leaf area (cm^2) at different days after planting			
	30	45	60	75
S_0As_0	31.38 ab	39.38 a	50.38 a	49.38 a
S_0As_1	13.70 eh	21.70cde	32.70 c-e	31.70 c-e
S_0As_2	26.76 b-c	34.76 ab	45.76 ab	42.76 ab
S_0As_3	14.91 d-g	22.91c-e	24.91 c-e	25.91 c-e
S_1As_0	34.69 a	42.69a	53.69 a	51.69 a
S_1As_1	20.10 cd	28.30bc	39.80 bc	38.80 bc
S_1As_2	18.75 de	26.75 b-d	37.75 b-d	33.75 b-d
S_1As_3	10.25 f-i	18.25 d-f	29.25 d-f	28.25 d-f
S_2As_0	20.84 cd	27.84 bc	38.84 bc	34.82 bc
S_2As_1	15.56 d-f	21.22 c-e	32.22 c-e	30.22 c-e
S_2As_2	8.587 g-i	12.40 fg	23.40 fg	22.10 fg
S_2As_3	9.350 f-i	17.35 ef	28.32 ef	27.35 ef
S_3As_0	9.197 g-i	17.20 ef	28.20 ef	28.27 ef
S_3As_1	7.240 i	8.433 g	19.43 g	20.4 g
S_3As_2	8.573 hi	16.57 e-g	27.57 e-g	26.17 e-g
S_3As_3	7.20 i	8.33 g	19.3 g	20.32 g
LSD value	8.71	8.45	8.74	5.39
CV(%)	13.46	14.46	17.88	14.39
Level of significance	*	*	*	*

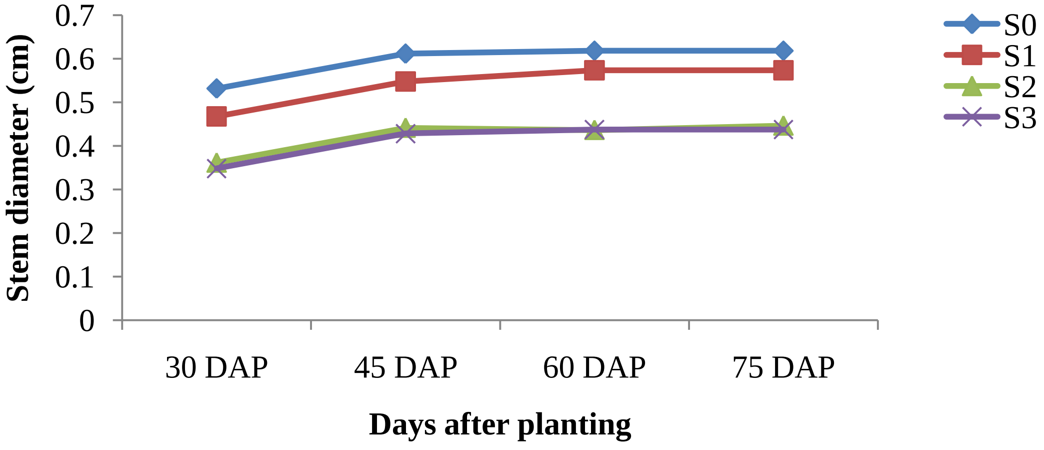
As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3, 100 g sawdust kg^{-1} soil.
* Indicates 5% level of significance
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.6 Stem diameter (cm)

Stem diameter of potato showed significant result among sawdust levels (S_0, S_1, S_2 and S_3) at 30, 45, 60 and 75 DAP (Appendix VIII). Figure 13 showed that effect of sawdust on stem diameter was antagonistic which indicated that the stem diameter decreased drastically with increasing sawdust levels. The widest stem diameter was recorded at 75 DAP in S_0 (0.61 cm) and the narrowest was recorded at 30 DAP in S_3 (0.34 cm) (Figure 13).

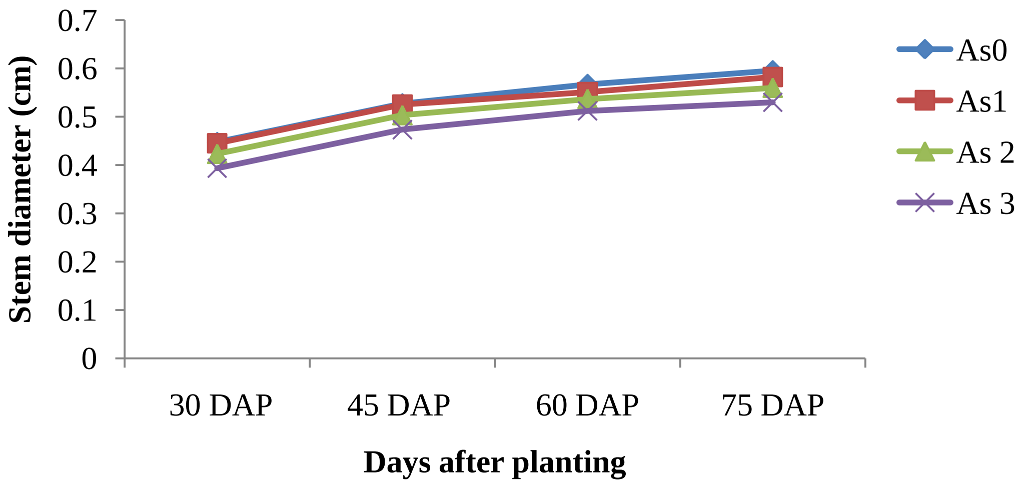
Stem diameter of potato was also statistically influenced by different As levels at 30, 45, 60 and 75 DAP (Appendix VIII). Figure 14 showed that stem diameter decreased with increasing the As levels in soil because high concentration (75 mg As kg^{-1} soil) create toxicity in soil. The widest stem diameter was recorded at 75 DAP in As_0 (0.61 cm) and the narrowest stem diameter was recorded at 30 DAP in As_3 (0.393 cm) (Figure 14). This result agreed with Hussain (2012).

Combined effect of sawdust and As levels in terms of stem diameter of potato exposed significant variation among treatment combinations at 30, 45, 60 and 75 DAP (Appendix VIII). It was remarked that the widest stem was recorded in As_2S_0 (0.716 cm) which was statistically similar to As_0 (0.603 cm), and As_1S_0 (0.603) whereas the narrowest was recorded in As_3S_2 (0.26 cm) at 30 DAP (Table 4).



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure13. Effect of sawdust on stem diameter at different days after planting (DAP) [LSD value = 0.0451, 0.0461, 0.0463 and 0.0595 at 30, 45, 60 and 75 DAP, respectively]



[As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

Figure14. Effect of As levels on stem diameter at different days after planting (DAP) [LSD value = 0.0451, 0.0461, 0.0463 and 0.0595 at 30, 45, 60 and 75 DAP, respectively]

Table 4. Combined effect of sawdust and As levels on stem diameter at different days after planting (DAP) of potato

Treatment	retemaid metSat different days after planting			
	30	45	60	75
S_0As_0	0.533 a	0.613 a	0.609 a	0.603 a-c
S_0As_1	0.506 ac	0.586 a-c	0.604 ab	0.603 ac
S_0As_2	0.566 a	0.646 a	0.604 ab	0.716 a
S_0As_3	0.476 ad	0.556 a-d	0.590 a-c	0.663 ab
S_1As_0	0.476 ad	0.556 a-d	0.533 a-e	0.576 b-d
S_1As_1	0.476 ad	0.556 a-d	0.556 a-e	0.510 c-f
S_1As_2	0.440 be	0.520 b-e	0.566 a-d	0.543 c-e
S_1As_3	0.406 de	0.486 de	0.580 a-d	0.536 c-e
S_2As_0	0.423 ce	0.5033 c-e	0.553 a-e	0.403 fg
S_2As_1	0.356 ef	0.4367 ef	0.513 b-f	0.370 g
S_2As_2	0.260 g	0.340 g	0.406 g	0.436 e-g
S_2As_3	0.373 ef	0.453 ef	0.490 d-g	0.460 d-g
S_3As_0	0.373 ef	0.453 ef	0.433 fg	0.393 fg
S_3As_1	0.293 fg	0.373 fg	0.473 eg	0.443 e-g
S_3As_2	0.353 ef	0.433 ef	0.500 cf	0.453 e-g
LSD value	0.092	0.092	0.092	0.119
CV(%)	13.53	11.39	10.29	13.18
Level of significance	*	*	*	*

As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil

* Indicates 5% level of significance

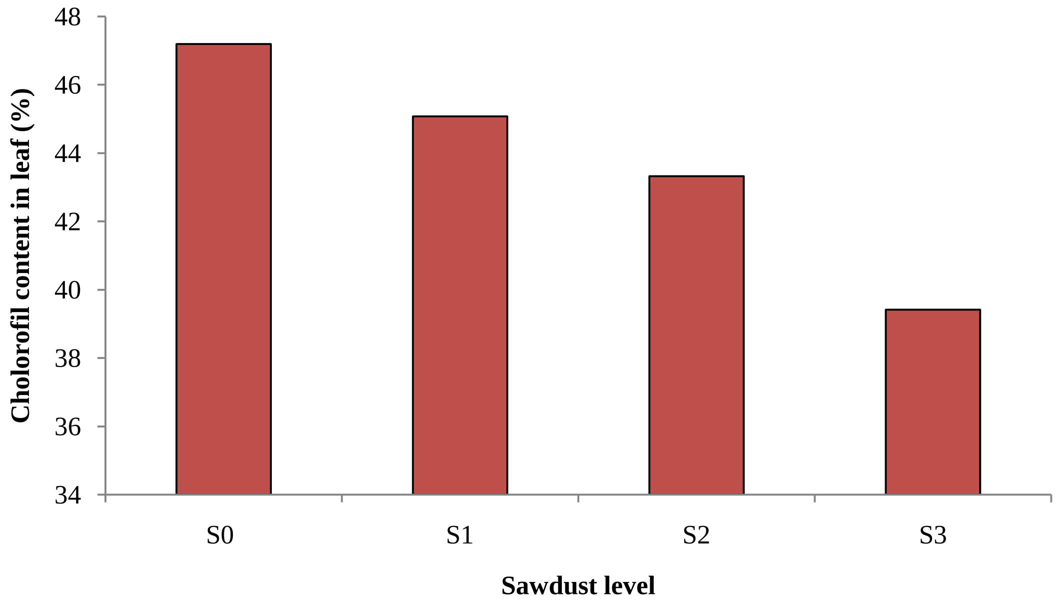
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.7 Chlorophyll content of mature leaf

Chlorophyll content of leaf was significantly affected by different sawdust levels (Appendix XI). Figure 15 indicated that there was an antagonestic relationship between sawdust levels and chlorophyll content of leaf. Chlorophyll content of leaf decreased with increasing the sawdust levels. The maximum chlorophyll content in leaf was recorded in S_0 (47.19%) which was statistically similar to S_1 (45.08%) and to S_2 (43.32%) while, the minimum was found from S_3 (39.42%) (Figure15).

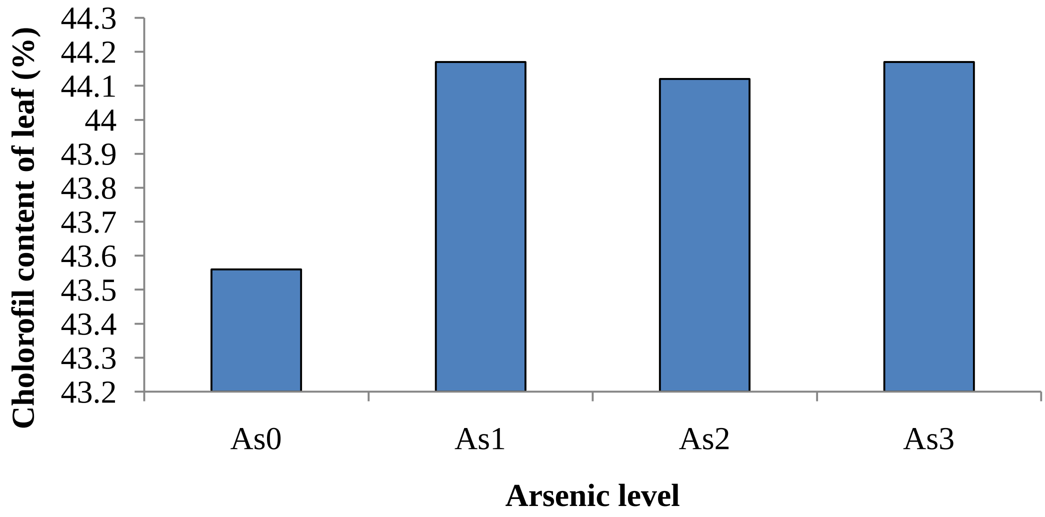
No significant relation was observed between chlorophyll content in leaf and different As levels (Appendix XI). Numerically the highest chlorophyll content in leaf was recorded from both As_1 (44.17%) and As_3 (44.17%) while the minimum (43.56%) was in As_0 (Figure 16).

Treatment combinations of different sawdust and As levels significantly influenced the chlorophyll content of leaf (Appendix XI). Chlorophyll content of leaf was observed maximum in As_0S_0 (48.44%) which was statistically similar to As_0S_0 (48.44%), As_1S_0 (46.53%), As_2S_0 (47.13%), As_3S_0 (46.67%), As_0S_1 (41.27%), As_1S_1 (47.2%), As_2S_1 (47.13%), As_3S_1 (44.73%), As_0S_2 (44.9%), As_1S_2 (45.2%), As_2S_2 (40.43 %), As_3S_2 (42.73%), As_2S_3 (41.77%) and As_3S_3 (42.53%) while the minimum was found in As_0S_3 (35.63%) (Figure 17).



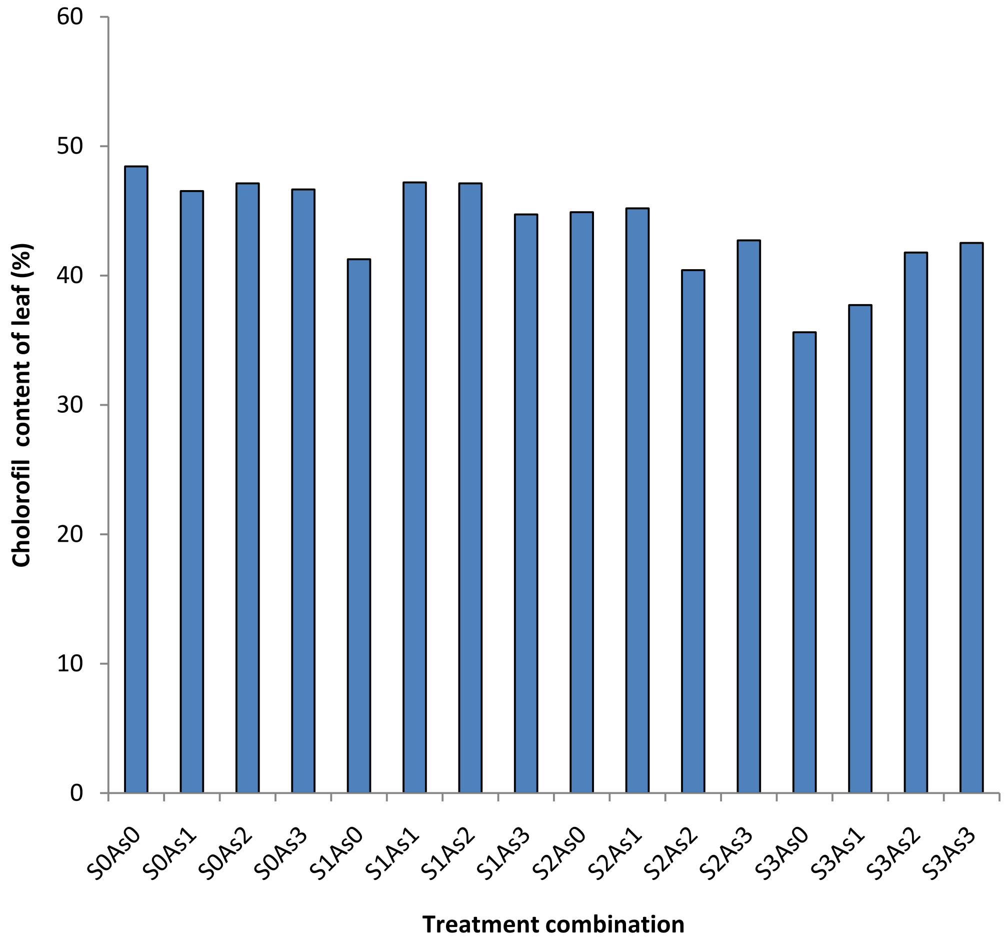
[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure15. Effect of sawdust related to chlorophyll content of leaf [LSD value = 4.643]



[As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil,]

Figure16. Effect of As on chlorophyll content of leaf



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil and As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil,]

Figure 17. Combined effects of sawdust and As levels on chlorophyll content of leaf [LSD value = 9.286]

4.8 Stem dry matter content (%)

This research work exhibited significantly distinct variations in stem dry matter content among different sawdust levels (Appendix IX). Figure18 showed that stem dry matter content increased with increasing sawdust levels. The maximum dry matter content was recorded in S_3 (11.61) which was statistically similar to S_2 (9.96%) while the minimum was found in S_0 (8.97%) (Figure 18).

Effects of different As levels on stem dry matter content was non-significant (Appendix IX). Numerically the maximum dry matter content was recorded in As_1 (10.55) while the minimum was found in As_2 (9.16 %) (Table 5). 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. Hussain (2012) mentioned that shoot dry matter content (%) of potato stem increased up to 10 mg As kg^{-1} soil and thereafter decreased with increasing As levels. Present study showed that there was no significant variation among different As levels more than 10 mg As kg^{-1} soil due to high concentration creating toxicity in soil.

Combined effects of sawdust and As influenced the dry matter content of stem (Appendix IX). It was observed that the maximum dry matter content of stem was obtained from As_1S_3 (13.52 %) which was statistically similar to As_2S_0 (11.4%), As_2S_1 (10.49%), As_0S_2 (10.19%), As_2S_2 (10.44%), As_3S_2 (10.42%) and As_0S_3 (12.08%) whereas, the minimum was recorded in As_2S_1 (7.53%) which was statistically similar to As_2S_1 (7.53%), As_0S_0 (8.68%), As_1S_0 (7.55%), As_3S_0 (8.57%), As_0S_1 (9.527%), As_1S_1 (10.49%), As_0S_2 (10.19%), As_1S_2 (10.44%), As_2S_2 (8.69%) and As_3S_2 (10.42%) (Table 6).

4.9 Tuber flesh dry matter content (%)

This research work showed distinct variations in tuber flesh dry matter content with different sawdust levels (Appendix IX). Figure18 showed that tuber flesh dry matter content increased with increasing sawdust levels in soil. The maximum dry matter content was recorded in S_3 (17.77%) which was statistically similar to S_2 (17.38%) and S_1 (17.12%) while the minimum was found in S_0 (16.32%) which was statistically similar to S_1 (17.12%) and S_2 (17.38%) (Table 5).

Effect of different As levels on stem dry matter content was non-significant (Appendix IX). Numerically the maximum dry matter content was recorded in As_2 (18.37%) while the minimum was found in As_0 (15.94%) (Table 5). Hussain (2012) showed the same trend of result.

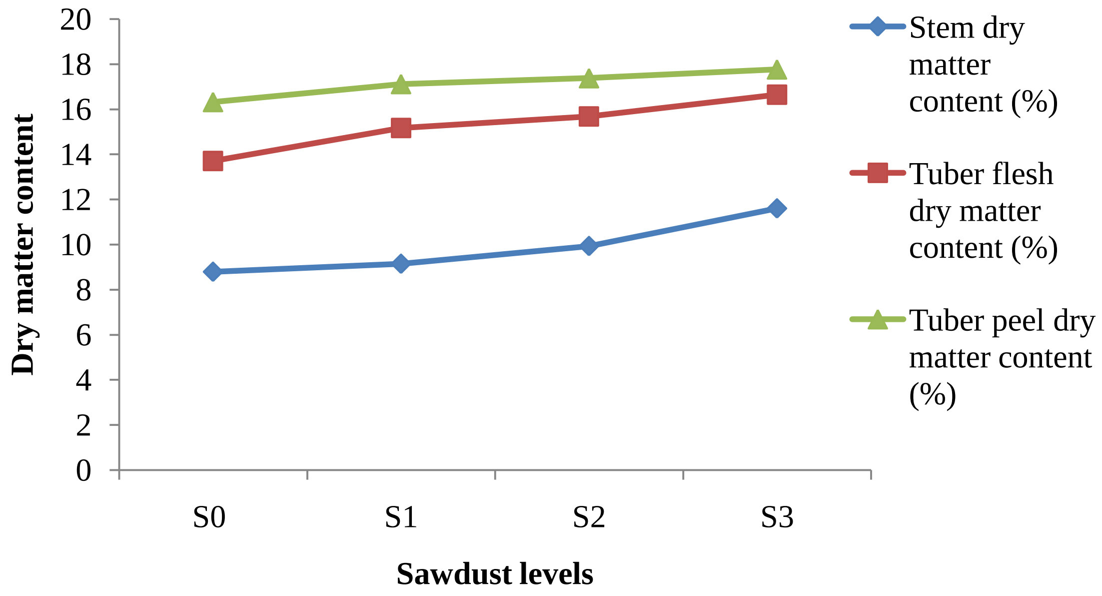
Dry matter content of tuber flesh was influenced by treatment combinations of sawdust and As levels (Appendix IX). The maximum dry matter content of stem was obtained from As_2S_2 (17.58 %) which was statistically similar to As_3S_0 (17.35%), As_1S_1 (16.95), As_3S_1 (17.37), As_0S_2 (17.35), As_0S_3 (17.24), As_1S_3 (17.68), As_2S_3 (18.87) and As_3S_3 (17.09) whereas; the minimum was recorded in As_0S_1 (12.95) (Table 6).

4.10 Tuber peel dry matter content (%)

Dry matter content of tuber peel varied significantly with different sawdust levels (Appendix IX). Figure18 showed that tuber peel dry matter content increased with increasing sawdust levels. The maximum dry matter content was recorded in S_3 (16.65%) which was statistically similar to S_2 (15.68%) and S_1 (15.67%) while the minimum was found from S_0 (0 .13%) (Figure 18). The experiment indicated that increasing of sawdust level in soil slightly increase the dry matter content of tuber peel upto 100g sawdust kg^{-1} soil.

Effect of different As levels on tuber peel dry matter content was non-significant (Appendix IX). Numerically the maximum dry matter content was recorded in As_2 (16.14%) while the minimum was found in As_1 (14.72 %) (Table 5).

Dry matter content (%) of tuber peel was influenced by combined effects of sawdust and As levels the (Appendix IX). It was observed that the maximum dry matter content of stem was obtained from As_3S_2 (19.29%) which was statistically similar to As_3S_0 (17.35%), As_1S_1 (16.95%), As_3S_1 (17.37%), As_0S_2 (17.35%), As_0S_3 (17.24%), As_1S_3 (17.68%), As_2S_3 (18.87%) and As_3S_3 (17.09%) whereas, the minimum was recorded in As_0S_0 (14.47%) (Table 6).



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 18. Effect of sawdust levels on dry matter content. [LSD value = 1.679, 1.391 and 1.544 in stem, tuber flesh and tuber peel dry matter content (%) respectively]

Table 5. Effect of As levels on dry matter content

Treatments	Stem dry matter content (%)	Tuber flesh dry matter content (%)	Tuber peel dry matter content (%)
As_0	10.12	15.94	15.02
As_1	10.55	16.56	14.72
As_2	9.165	17.37	16.14
As_3	9.648	17.72	15.82
CV (%)	8.46	12.04	9.76
Level of significance	NS	NS	NS

As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

NS indicates non-significance

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 6. Combined effects of sawdust and As levels on dry matter content

Treatments	Stem dry matter content (%)		Tuber flesh dry matter content (%)		Tuber peel dry matter content (%)	
S_0As_0	8.68	c-d	13.92	c-d	14.47	D
S_0As_1	7.75	d	12.95	d	16.09	b-d
S_0As_2	11.4	a-c	13.1	d	15.87	Cd
S_0As_3	8.757	b-d	14.88	a-d	17.35	a-c
S_1As_0	9.527	b-d	15.53	a-d	16.22	b-d
S_1As_1	10.49	a-d	14.41	b-d	16.95	a-d
S_1As_2	7.533	d	16.82	a-c	15.68	Cd
S_1As_3	7.617	d	15.9	a-d	17.37	a-c
S_2As_0	10.19	a-d	16.35	a-c	17.35	a-c
S_2As_1	10.44	a-d	16.7	a-c	17.76	a-c
S_2As_2	8.697	c-d	17.58	a	19.08	A
S_2As_3	10.42	a-d	15.98	a-d	19.29	A
S_3As_0	12.08	a-b	14.29	b-d	17.24	a-d
S_3As_1	13.52	a	14.81	a-d	17.68	a-c
S_3As_2	9.027	b-d	17.07	a-b	18.87	Ab
S_3As_3	11.8	a-c	16.53	a-c	17.09	a-d
LSD Value	3.359		2.782		3.089	
CV (%)	8.560		9.76		12.04	
Level of significance	*		*		*	

As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3, 100 g sawdust kg^{-1} soil

* indicates 5% level of significance

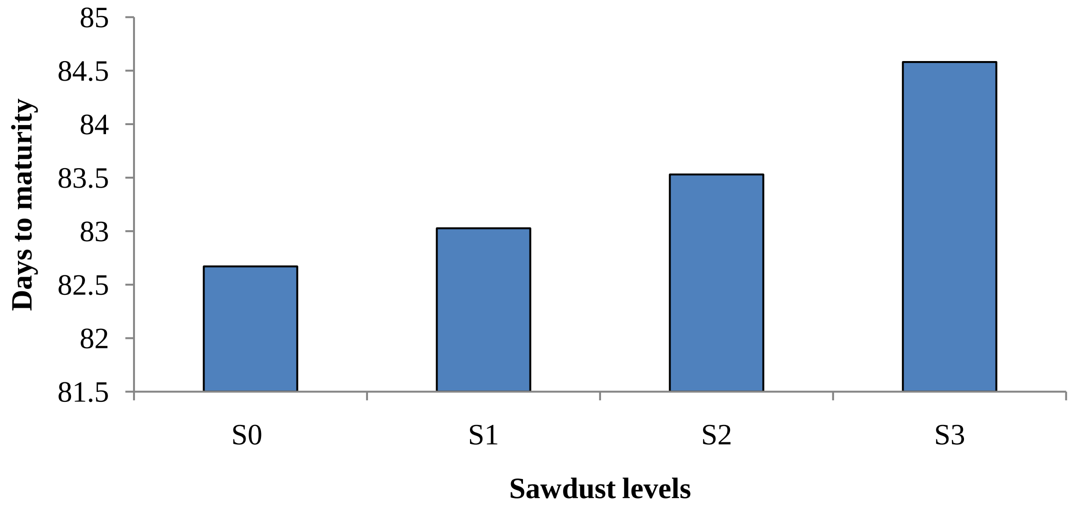
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

4.11 Days to maturity (Visual observation)

When leaf of potato plant was 60% yellow the plant considered as 100% mature. Days to maturity was significantly affected by sawdust levels (Appendix III). Figure 19 showed that duration of plant maturity increasd with the increasing of sawdust level. The maximum period required to maturity in S_3 (84.58 days) which was statistically similiar to S_2 (83.53) while minimum period required in S_0 (82.67 days) (Figure 19).

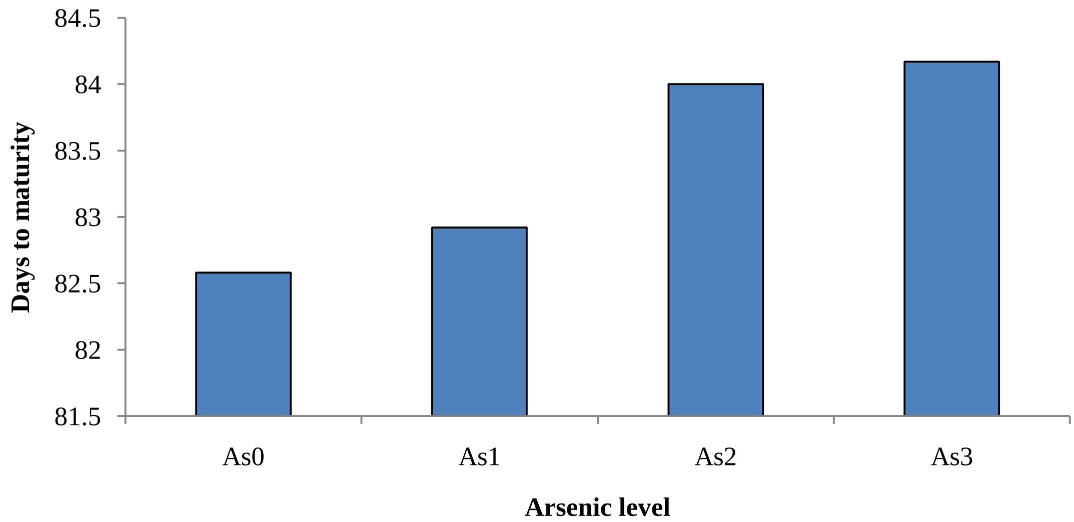
Days to maturit**y** was significantly affected by As levels (Appendix II). Figure 20 showed that duration of plant maturity increasd with the increasing of As levels in soil. The maximum period required to maturity in As_3 (84.17 days) which was statistically similiar to As_2 (84.0 days) while, minimum period required in As_0 (82.58) which was statistically similiar to As_1 (82.92 days) (Figure 20). Days to maturity prolonged with increasing sawdust levels.

Days to maturity of potato tubers was significantly influenced by combined effects of sawdust and As levels (Appendix II). The treatment combination As_0S_0 required minimum duration (82 days) for maturity where maximum recorded in As_2S_2 (85.67 days) which was statistically similar to As_2S_1 (85), As_1S_2 (84.33), As_2S_2 (85.67) and As_3S_2(85) (Figure 21).



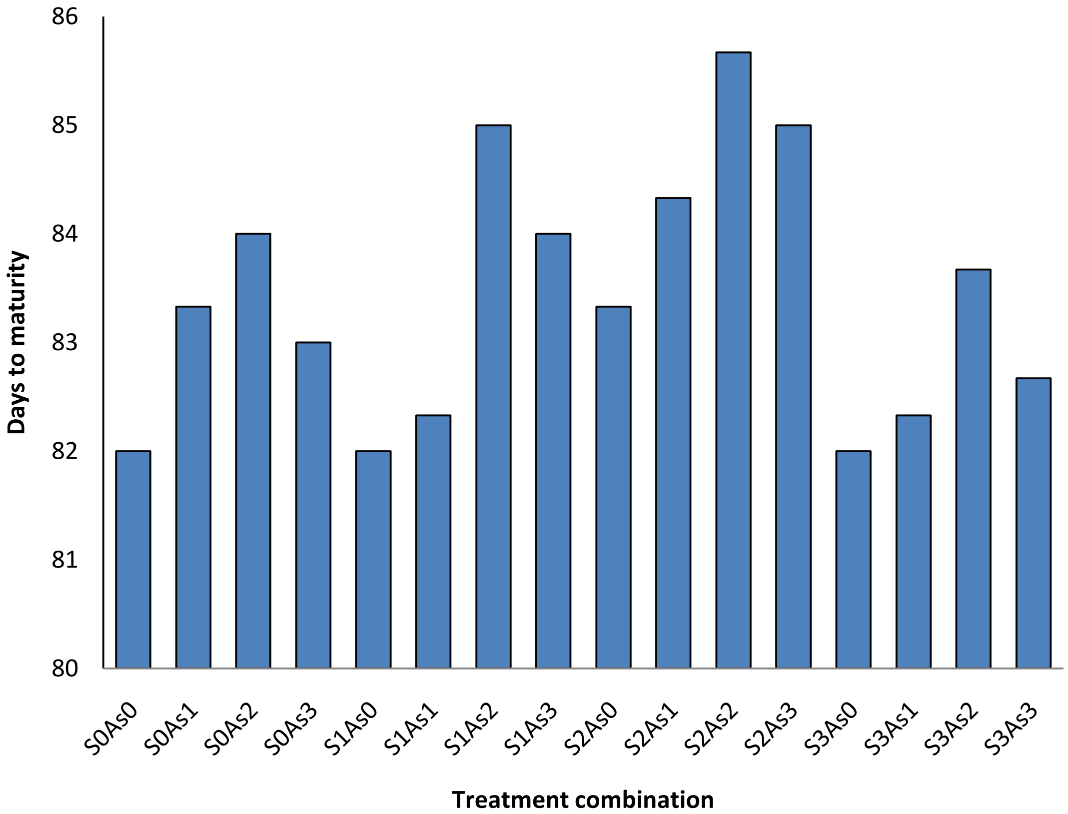
[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 19. Effect of sawdust levels on days to maturity [LSD value = 0.71]



[As_0, Control; As_1, 25 mg As kg-1 soil; As_2, 50 mg As kg-1 soil; As_3, 75 mg As kg-1 soil]

Figure 20. Effect of As levels on days to maturity [LSD value = 0.729]



[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil and As_0, Control; As_1, 25mg As kg^{-1} soil; As^2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil,]

Figure 21. Combined effects of sawdust and different As levels on days to maturity [LSD value = 1.42]

4.12 Number of tubers plant^{-1}

Number of tubers plant^{-1} varied significantly with different sawdust levels (Appendix VIII). Table 7 indicated that number of tubers hill^{-1} decreased gradually with increasing sawdust levels. The highest number of tuber plant^{-1} was recorded in S_0 (17.42) while, the minimum was found from S_2 (9.25) which was statistically similar to S_3 (9.50).

The number of tubers plant^{-1} was significantly affected by different As levels (Appendix VIII). Table 8 showed that tuber numbers plant^{-1} decreased with increasing As levels. As_0 treatment produced maximum number of tubers hill^{-1} (12.58) which was statistically similar to As_1 (12.42) and As_2 (12.33) while the minimum (9.917) was obtained from As_3 because As_3 (100 mg As kg^{-1} soil) create toxicity (Table 8). This result agreed with Hussain (2012).

Combined effect of different sawdust and As levels showed statistically significant variation in number of tubers hill^{-1} (Appendix VIII). The maximum number of tubers hill^{-1} was recorded from As_2S_0 (21) while the minimum was recorded from As_3S_2 (6.66) (Table 9).

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

Yield of tuber plant^{-1} varied significantly with different sawdust levels (Appendix IX). Table 7 indicated that yield of tuber plant^{-1} decreased gradually with increasing sawdust levels. The highest tuber yield plant^{-1} (492.8 g) was recorded in control S_0 while, the minimum was found from S_3 (218.0 g).

Yield of tuber plant^{-1} varied significantly with different As levels (Appendix IX). The yield of tuber plant^{-1} decreased with increasing As levels. The highest tuber yield plant^{-1} (373.2 g) recorded from As_0 which was statistically similar to As_1 (346.4 g) while the minimum was recorded in As_3 (304.4 g) (Table 8). 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 refered 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 (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). Hussain (2012) stated that application of 10 mg As kg^{-1} soil increased the most yield contributing characters.

Treatment combination of different sawdust and As levels significantly influenced the yield of tuber plant^{-1} (Appendix IX). The yield of tuber plant^{-1} was observed maximum in As_0S_0 (543.6 g) treatment combinations which was statistically similar to As_3S_0 (539.6 g) while the minimum was found under As_3S_3 (172.2 g) treatment combinations which was statistically similar to As_3S_2 (240.3 g), As_1S_3 (220.8 g) and As_2S_3 (217.7 g) (Table 9).

Table 7. Effect of sawdust levels related to number of tubers plant^{-1} and yield

Treatments	Number of tubers plant^{-1}	Yield of tuber plant^{-1} (g)
S_0	17.42 a	492.8 a
S_1	11.08 b	403.2 b
S_2	9.250 c	277.1 c
S_3	9.500 c	218.0 d
LSD Value	0.93	20.02
CV (%)	6.03	12.70
Level of significance	**	**

S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil

**, * Indicate 1% and 5% level of significance respectively

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. Effect of As levels related to number of tubers plant^{-1} and yield

Treatments	Number of tubers plant^{-1}	Yield of tuber plant^{-1} (g)
As_0	12.58 a	373.9 a
As_1	12.42 a	346.4 ab
As_2	12.33 a	330.5 b
As_3	9.91 b	304.4 c
LSD Value	0.93	20.02
CV (%)	6.03	12.70
Level of significance	*	*

As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

* Indicates 5% level of significance

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 9. Combined effects of sawdust and As levels on number of tubers plant^{-1} and yield

Treatments	Number of tubers plant^{-1}	Yield of tuber plant^{-1} (g)
S_0As_0	18.67 b	543.6 a
S_0As_1	15.33 c	433.2 bc
S_0As_2	21.00 a	455.0 b
S_0As_3	14.67 c	539.6 a
S_1As_0	10.67 de	442.4 bc
S_1As_1	12.33 d	430.4 bc
S_1As_2	10.67 de	370.5 cd
S_1As_3	10.67 de	369.7 cd
S_2As_0	8.667 fg	269.3 ef
S_2As_1	11.33 de	301.0 de
S_2As_2	10.33 ef	297.9 de
S_2As_3	6.660 h	240.3 efg
S_3As_0	12.33 d	240.3 efg
S_3As_1	10.67 de	220.8 fg
S_3As_2	7.33 gh	238.5 efg
S_3As_3	7.66 gh	172.2 g
LSD Value	1.863	74.43
CV (%)	6.03	12.70
Level of significance	*	*

S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil and As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

* Indicates 5% level of significance

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 Specific gravity of tuber

Specific gravity of tuber varied significantly with different sawdust levels (Appendix XI). The highest specific gravity of tuber was recorded in S_1 (1.039) while, the minimum was found from S_2 (1.013) (Table 7). The experiment indicated that treated 10 g sawdust kg^{-1} soil (S_1) produced the maximum specific gravity of tuber compared to those of other treatments (Table 10).

Specific gravity of tuber also varied significantly with different As levels (Appendix XI). Present study showed that specific gravity gradually increased with increasing As levels. The highest Specific gravity of tuber recorded from As_2 (1.035) which was statistically similar to As_3 (1.032) while the minimum was in As_0 (1.013) (Table 11).

Specific gravity of tuber was significantly influenced by the treatment combinations of sawdust and As levels (Appendix XI). Specific gravity of tuber was observed maximum in As_0S_2 (1.023) while the minimum was found in As_0S_1 (1.005) (Table12).

4.15 Total soluble solid of tuber

Total soluble solid of tuber varied significantly with different sawdust levels (Appendix XI). The experiment indicated that sawdust had antagonistic relation with total soluble solid of tuber . Table 10 showed that total soluble solid decreased with increasing sawdust levels. The highest value of total soluble solid of tuber was recorded in S_0 (6.33) while the lowest was found from S_2 (5.5) which was statistically similar to S_3 (5.87) (Table 10).

Total soluble solid of tuber varied significantly with different As levels (Appendix XI). Table 11 showed that total soluble solid of tuber decreased with increasing As levels. The maximum total soluble solid of tuber recorded from As_0 (6.37) while the minimum from As_1 (5.70) (Table11).

Treatment combinations of different sawdust and As levels significantly influenced the total soluble solid of tuber (Appendix XI). Total soluble solid of tuber was observed maximum in As_0S_0 (7.0) which was statistically similar to As_3S_0 (6.833), As_1S_1 (6.5) and As_0S_3 (6.5) while the minimum was found from As_1S_2 (5.0) treatment combination which was also statistically similar to As_1S_0 (5.5), As_3S_1 (5.33), As_3S_2 (5.0) and As_2S_3 (5.16) (Table 12).

Table 10. Effect of sawdust on specific gravity of tuber and total soluble solid

Treatments	Specific gravity of tuber	Total soluble solid of tuber (%)
S_0	1.029 b	6.333 a
S_1	1.039 a	5.958 ab
S_2	1.013 d	5.500 c
S_3	1.019 c	5.875 bc
LSD Value	0.0037	0.428
CV (%)	3.599	8.690
Level of significance	**	*

S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil

**, * Indicate 1% and 5% level of significance respectively.

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. Effect of As related to specific gravity of tuber and total soluble solid

Treatments	Specific gravity of tuber	Total soluble solid of tuber (%)
As_0	1.0135 c	6.375 a
As_1	1.0196 b	5.708 b
As_2	1.0359 a	5.792 b
As_3	1.0328 a	5.792 b
LSD Value	0.0037	0.428
CV (%)	3.59	8.69
Level of significance	*	*

[As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

* Indicates 5% level of significance

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 12. Combined effects of sawdust and As levels related to specific gravity of tuber and total soluble solid

Treatments	Specific gravity of tuber		Total soluble solid of tuber (%)	
S_0As_0	1.057	ij	7.00	a
S_0As_1	1.015	f-h	5.50	de
S_0As_2	1.013	g-i	6.00	b-d
S_0As_3	1.020	e-g	6.83	a-b
S_1As_0	1.005	j	6.00	b-d
S_1As_1	1.040	d	6.50	a-c
S_1As_2	1.007	ij	6.00	b-d
S_1As_3	1.026	e	5.33	d-e
S_2As_0	1.063	a	6.00	b-d
S_2As_1	1.053	b	5.00	e
S_2As_2	1.016	f-h	6.00	b-d
S_2As_3	1.010	h-j	5.00	e
S_3As_0	1.042	c-d	6.50	a-c
S_3As_1	1.049	b-c	5.83	c-e
S_3As_2	1.018	e-g	5.16	de
S_3As_3	1.021	e-f	6.00	b-d
LSD Value	0.007		0.8562	
CV (%)	3.59		8.69	
Level of significance	*		*	

As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil

* Indicates 5% level of significance

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

4.16 Marketable and non marketable yield

The results indicated that there was no significant difference in the effect of sawdust on potato in respect of production of marketable and non marketable tubers on the basis of % by number (Appendix X). It was observed that numerically maximum marketable potato produce in S_1 (58.87%) where the minimum was recorded from S_0 (52.61%) and numerically maximum non marketable tuber produced in S_0 (47.41%) where the minimum produced in S_2 (41.13%) (Table16).

On the basis of % by weight the marketable and non marketable tuber hill^{-1} was significantly varied among different sawdust levels. Maximum % by weight marketable potato produced in S_1 (86.94%) which was statistically similar to S_0 (84.33%) and S_2 (85.99%) where the minimum produced in S_3 (79.82%) which was statistically similar to S_0 (84.33%) and S_2 (85.99%) (Table16). The Maximum % by weight non marketable potato produced in S_3 (20.18) which was statistically similar to S_0 (15.67%) and S_2 (14.01%) where the minimum produced in S_1 (13.06%) which was statistically similar to S_0 (15.67%) and S_2 (14.01%) (Table16).

Effect of As levels on marketable and non marketable tubers (% by number) was non-significant (Appendix X). It was observed that numerically the maximum marketable potato (% by number) produce in As_1 (56.4) where minimum was recorded in As_3 (52.42%). Similar trend was observed for nonmarketable tubers (% by number) where the maximum was recorded from As_3 (47.58%) and minimum was recorded in As_1 (43.61%) treatment (Table17).

On the basis of marketable and non marketable tubers hill^{-1} (% by weight) was insignificant among different As levels (Appendix X). Numerically the maximum number of marketable and nonmarketable tubers (% by weight) was recorded from As_3 (86.36%) and As_1 (18.89%) where minimum was recorded from As_1 (81.11%) and As_0 (13.64%), respectively (Table17).

Combined effects of different sawdust and As levels showed statistically significant variation on grade of tubers on the basis of marketable tubers % by number (Appendix X). The maximum marketable tuber (% by number) was recorded from As_2S_3 (64.87%) which was statistically similar to As_1S_0 (47.37%), As_2S_0 (61.1%), As_3S_0 (63.7%), As_0S_1 (65.73%), As_1S_1 (64.93%), As_3S_1 (43.63%), As_0S_2 (61.5%), As_1S_2 (62.37%), As_2S_2 (61.6%), As_3S_2 (50%), As_0S_3 (54.17%), As_1S_3 (50.93%), and As_3S_3 (52.3%) and the minimum was found in As_2S_1 (37.6%) which was statistically similar to As_0S_0 (38.27%), As_1S_0 (47.37%), As_2S_0 (61.1%), As_2S_1 (37.6%), As_3S_1 (43.63%), As_0S_2 (61.5%), As_1S_2 (62.37%), As_2S_2 (61.6%), As_3S_2 (50%), As_0S_3 (54.17%), As_1S_3 (50.93%) and As_3S_3 (52.37%) (Table18).

The maximum non marketable tuber (% by number) was recorded from As_2S_1 (62.4%) which was statistically similar to As_0S_0 (61.73%), As_1S_0(52.67%), As_2S_0 (38.9%), As_3S_1 (56.37%), As_0S_2 (38.5%), As_1S_2 (37.63%), As_2S_2 (38.4%), As_3S_2 (50%), As_0S_3 (45.83%), As_1S_3 (49.07%) and As_3S_3 (47.63%) where the minimum (34.27%) was found in As_0S_1 which was statistically similar to As_1S_0 (52.67%), As_2S_0 (38.9%), As_1S_1 (35.07%), As_3S_1 (56.37%), As_0S_2 (38.5%), As_1S_2(37.63%), As_2S_2 (38.4%), As_3S_2 (50%), As_0S_3 (45.83%), As_1S_3 (49.07%) and As_3S_3 (47.63%).

The maximum marketable tuber (% by weight) was recorded from As_3S_0 (91%) which was statistically similar to As_0S_0 (75.73), As_1S_0 (86.73%), As_2S_0 (83.87%), As_0S_1 (89.23%), As_1S_1 (84.7%) As_2S_1 (85.93%), As_3S_1 (87.9%), As_0S_2 (89.63%), As_1S_2 (82.53%), As_2S_2 (84.93%), As_3S_2 (86.87%), As_0S_3 (90.83%), As_2S_3 (80.77%) and As_3S_3 (77.2%) where the minimum (70.47%) was found in As_1S_3 which was statistically similar to As_0S_0 (75.73%), A_2S_0 (83.87%), As_1S_2 (82.53%), As_2S_3 (80.77%) and As_3S_3 (77.2%) (Table 18).The maximum amount of non-marketable tuber (% by weight) was recorded from As_1S_3 (29.53%) which was statistically similar to As_0S_0 (24.27%), As_2S_0 (16.13%), As_1S_2 (17.47%), As_2S_3 (19.23%) and As_3S_3 (22.8%) where minimum was recorded from A_3S_0 (9.0) which was statistically similar to As $_2S_0$ (16.13%), As_0S_1 (10.77%), As_1S_1 (15.3%), As_2S_1 (14.07%), As_3S_1 (12.1%), As_0S_2 (10.37%), As_1S_2 (17.47%), As_2S_2 (15.07%), As_3S_2 (13.13%), As_2S_3 (19.23%) and As_3S_3 (22.8%) (Table18).

Table 13. Effect of sawdust levels on grade of tubers (% by number and % by weight)

Treatments	Marketable tubers hill^{-1} (% by number)	Non marketable tubers hill^{-1} (% by number)	Marketable tuber (% by weight)	Non Marketable tuber (% by weight)
S_0	52.61	47.41	84.33 ab	15.67 ab
S_1	52.97	47.03	86.94 a	13.06 b
S_2	58.87	41.13	85.99 ab	14.01 ab
S_3	55.58	44.42	79.82 b	20.18 a
LSD Value	-	-	7.084	7.084
CV (%)	3.4	2.7	9.98	5.34
Level of significance	NS	NS	*	*

S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil
* Indicates 5% level of significance and NS indicates non significance
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. Effect of As levels on grade of tubers (% by number and % by weight)

Treatments	Marketable tubers hill^{-1} (% by number)	Non marketable tubers hill^{-1} (% by number)	Marketable tuber (% by weight)	Non Marketable tuber (% by weight)
As_0	54.92	45.08	86.36	13.64
As_1	56.4	43.61	81.11	18.89
As_2	56.29	43.71	83.88	16.13
As_3	52.42	47.58	85.74	14.26
CV (%)	3.4	2.7	9.98	5.34
Level of significance	NS	NS	NS	NS

As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

NS indicates non significance

Table 15. Combine effects of sawdust and As levels on grade of (% by number and % by weight)

Treatments	Marketable tubers $hill^{-1}$ (% by number)		Non marketable tubers $hill^{-1}$ (% by number)		Marketable tuber (% by weight)		Non Marketable tuber (% by weight)	
S_0As_0	38.27	bc	61.73	ab	75.73	bc	24.27	ab
S_0As_1	47.37	a-c	52.67	a-c	86.73	ab	13.27	bc
S_0As_2	61.10	a-c	38.90	a-c	83.87	a-c	16.13	a-c
S_0As_3	63.70	ab	36.33	bc	91.00	a	09.00	c
S_1As_0	65.73	a	34.27	c	89.23	ab	10.77	bc
S_1As_1	64.93	a	35.07	c	84.70	ab	15.30	bc
S_1As_2	37.60	c	62.40	a	85.93	ab	14.07	bc
S_1As_3	43.63	a-c	56.37	a-c	87.90	ab	12.10	bc
S_2As_0	61.50	a-c	38.50	a-c	89.63	ab	10.37	bc
S_2As_1	62.37	a-c	37.63	a-c	82.53	a-c	17.47	a-c
S_2As_2	61.60	a-c	38.40	a-c	84.93	ab	15.07	bc
S_2As_3	50.00	a-c	50.00	a-c	86.87	ab	13.13	bc
S_3As_0	54.17	a-c	45.83	a-c	90.83	a	9.167	c
S_3As_1	50.93	a-c	49.07	a-c	70.47	c	29.53	a
S_3As_2	64.87	a	35.13	c	80.77	a-c	19.23	a-c
S_3As_3	52.37	a-c	47.63	a-c	77.20	a-c	22.80	a-c
LSD Value	25.91		25.91		14.17		14.17	
CV (%)	3.4		2.7		9.98		5.34	
Level of significance	*		*		*		*	

S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil and As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil

* Indicates 5% level of significance

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

4.17 Arsenic content of tuber peel (mg kg^{-1})

leep rebut fo tnetnoc cinesrA varied significantly ($P \leq 0.01$) with different sawdust levels (Appendix XI). Table 19 showed that As content of tuber peel (mg kg $^{-1}$) decreased gradually with increasing sawdust levels. The highest leep rebut fo tnetnoc cinesrA was recorded in S_0 (4.164 mg kg^{-1}) while the minimum was found from S_3 (0.5658 mg kg^{-1}). Concentration of As in tuber peel drastically decreased with increasing sawdust levels (Table 19). Figure 22 showed that high negative correlation was observed between sawdust levels and As accumulation in tuber ($R^2 = 0.902$**) and there was a close negetive affainity beetween sawdust and As accumulation in tuber peel. Plant can only uptake As as As (III) and As (V). However it is possible when As complex hydrolysis in soil solution and make As (III) and As (V) but when sawdust or bioadsorbent was present in soil the As (III) and As (V) made bond with different cellulosic organic complex with soil colloid and produced intermediate complex among As, cellulosic compound and soil colloid. In this regards plant could not accumalate As. Sawdust have close affinity for heavy metal remediation form aqueous solution (Sud *et al.*, 2008). The sorption of heavy metals onto biomaterials is attributed to their constituents, which are mainly proteins, carbohydrates and phenolic compounds, since they contain functional groups such as carboxyls, hydroxyls and amines, which are able to attach to the metal ions (Choi and Yun, 2006). Adsorption of arsenite by the bioadsorbent (maize cob) modified with phosphoric acid/ammonia was 11 μg g^{-1}, which corresponds to 98% removal from a 550 μg As L^{-1} solution for an adsorbent dose of 50 mg ml^{-1} where the maize cob modified by phosphoric acid/urea removed 0.4 μg g^{-1} arsenate from a 300 μg As l^{-1} solution (Elizalde-González *et al.*, 2008). Arsenate and arsenite uptake by plants varies in different environment conditions but in biosorption techniques, arsenic be removed by a biological substrate, as a sorbent, bacteria, fungi, algae, or vascular plants surfaces based on passive binding of arsenic or other contaminants on cell wall surfaces containing special active functional groups.

Hence, more efforts are needed on addressing the molecular level behavior of arsenic in plants, kinetics of uptake, and transfer of As in plants with flowing waters, remobilisation through decay, possible methylation, and volatilization (Vithanage *et al*., 2012)

With 5 % eggshell addition the increase in soil pH may contribute to heavy rapeseed residue, metal immobilization by altering heavy metals into more stable in soils. Concentrations of - Cd and Pb were reduced by up to 67.9 and 93.2 % by addition of 5 % eggshell compared to control (Lee *et al*., 2013). The adsorption specificity of sawdust was Pb > Cu > Cd > Zn where the adsorption capacity of Pb and Cu onto NaOH-treated sawdust was increased 2~3 times compared to the untreated one (Lee *et al*., 2009*)*. Maximum biosorption capacity of the sawdust modified with ferric oxyhydroxides, evaluated by Langmuir adsorption model, was 9.259 mg g^{-1} and the adsorption capacity suggesting that the prepared chemically modified biosorbent has potential in remediation of Arsenic from contaminated soil water (Urik *et al*., 2012).

leep rebut fo tnetnoc cinesrA varied significantly ($P \leq 0.01$) with different As levels (Appendix XI). Table 20 showed that As content of tuber peel gradually increased with increasing As levels. The highest leep rebut fo tnetnoc cinesra recorded from As_3 (3.867 mg kg^{-1}) while the minimum was in As_0 (0.00 mg k g^{-1}) (Table 20). Figure 23 showed that high positive correlation was observed between Arsenic level in soil and As accumulation in tuber peel (R^2 = 0.937**). 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).

Treatment combination of sawdust level and different As levels influenced the leep rebut fo tnetnoc sA significantly ($P \leq 0.01$) (Appendix XI). cinesrA leep rebut fo tnetnoc was observed maximum in As_3S_0 (6.820 mg kg^{-1}) while no accumulation (0.000 mg kg^{-1}) was found from As_0S_0 (0.000 mg kg^{-1}), As_0S_1(0.000 mg kg^{-1}), As_0S_2 (0.000 mg kg^{-1}) and As_0S_3 (0.000 mg kg^{-1}) treatment combinations (Figure 24).

Treatment combinations of As_0S_0, As_0S_1, As_0S_2 and As_0S_3 showed that there was no (0.00 mg kg^{-1}) arsenic accumulation by tuber peel because As levels was control. As level As_1 (25mg As in kg^{-1} soil) was same four treatments $As_1S_{0,}$ $As_1S_{1,}$ As_1S_2 and As_1S_3 where As accumulation by tuber peel was (3.523, 2.1, 1.102 and 0.3967 mg kg^{-1} where sawdust level was S_0 (control) , S_1(10 g sawdustkg^{-1} soil), S_2 (50 g Sawdustkg^{-1} soil) and S_3 (100 g Sawdustkg^{-1} soil) (Figure 24). Figure 24 showed that only increasing of sawdust level the accumulation of As decreased in tuber peel. Sawdust acted as a bioadsorbent in soil and breakdown by microorganism wit presence of soil water and prodeuced cellulosic waste materials viz., acetamido, alcoholic, carbonyl, phenolic, amido, amino, sulphydryl groups etc.) by microorganism wit presence of soil water adsorb As by sawdust from Soil solution and make a intermediate complex between soil colloid and As. Sawdust has close affinity for heavy metal remediation form aqueous solution (Sud et. al., 2008). How much bioadsorbent in soil occurred more bisoroption process that why increasing of different sawdust level in a particular concentration of As, As content in tuber peel decreased (Figure 24). Result showed same trends in case of As_2 and As_3 Arsenic levels with S_0, S_1, S_2 and S_3 sawdust level [As_2S_0 (6.313 mg kg^{-1}), As_2S_1(4.43 mg kg^{-1}), As_2S_2 (2.277 mg kg^{-1}) and As_2S_3 (1.023 mg kg^{-1})] and [As_3S_0 (6.82 mg kg^{-1}), As_3S_1 (4.78 mg kg^{-1}), As_3S_2 (3.023 mg kg^{-1}) and As_3S_3(0.843 mg kg^{-1})].

4.18 Arsenic content of tuber flesh (mg kg^{-1})

As content of tuber flesh was strongly significant ($P \leq 0.01$) with different sawdust levels (Appendix XI). Table 19 showed that As content of tuber flesh (mg kg $^{-1}$) decreased gradually with increasing sawdust levels. The highest hself rebut fo tnetnoc cinesrA was recorded in S_0 (0.415 mg kg^{-1}) which is while, the minimum was found from S_3 (0.2015 mg kg^{-1}) (Table 19). Figure 22 showed that high negative correlation was observed between sawdust levels in soil and As accumulation in tuber flesh ($R^2 = 0.902^{**}$). As accumulation in tuber flesh decreased significantly with increasing of sawdust levels (Figure 22). Comparison of As accumulation in different levels of sawdust treatments, plant parts of potato clearly showed that translocation of As in tuber flesh edible parts was gradually lower to S_0 (0.4150 mg kg^{-1}), S_1 (0.390 mg kg^{-1}), S_2 (0.2569 mg kg^{-1}) and S_3 (0.2015 mg kg^{-1}) when sawdust levels was gradually higher.

hself rebut fo tnetnoc cinesrA varied significantly ($P \leq 0.01$) with different As levels (Appendix XI). Table 17 showed that As content of tuber flesh desaercni slevel sA fo gnisaercni htiw yllaudrg. The highest hself rebut fo tnetnoc cinesra recorded from As_3 (0.6236 mg kg^{-1}) while the minimum was in As_0 (0.00 mg kg^{-1}) (Table 17). High positive correlation was observed between Arsenic level in soil and As accumulation in tuber flesh ($R^2 = 0.924^{**}$). The (Figure 23) clearly incated that As accumulation in tuber flesh increased with the increasing As levels in soil. 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).

Treatment combination of different sawdust and As levels influenced the sA hself rebut fo tnetnoc significantly ($P \leq 0.01$) (Appendix XI). tnetnoc cinesrA hself rebut fo was observed maximum (1.083) in As_3S_0 while no As was found from As_0S_0(0.000), As_0S_1(0.000), As_0S_2(0.000) and As_0S_3(0.000) treatment combination (Figure 24). The result showed the similar trends in regards to As content in tuber peel. The result conclude that how much bioadsorbent in soil that occurred more bisoroption process that why increasing of different sawdust level in a particular concentration of As, As content in tuber flesh drastically decreased by only increasing of sawdust level. Sawdust acted as a bioadsorbent in soil and breakdown by microorganism with presence of soil water and prodeuced cellulosic waste materials viz. acetamido, alcoholic, carbonyl, phenolic, amido, amino, sulphydryl groups etc.) by microorganism with presence of soil water adsorb As by sawdust from soil solution and make a intermediate complex between soil colloid and As. Sawdust have close affinity for heavy metal remediation form aqueous solution (Sud *et al.*, 2008). How much bioadsorbent in soil occurred more bisoroption process that why increasing of different sawdust levels in a particular concentration of As , As content in tuber flesh decreased (Figure 24).

Table 16. Effect of sawdust on As content of peel and flesh of potato tuber

Treatments	As content in tuber peel	As content in flesh
S_0	4.1640 a	0.4150 a
S_1	2.8280 b	0.3900 b
S_2	1.6000 c	0.2569 c
S_3	0.5658 d	0.2015 d
LSD Value	0.09970	0.008426
CV (%)	5.250	6.660
Level of significance	**	**

[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

**, * Indicate 1% and 5% level of significance respectively

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

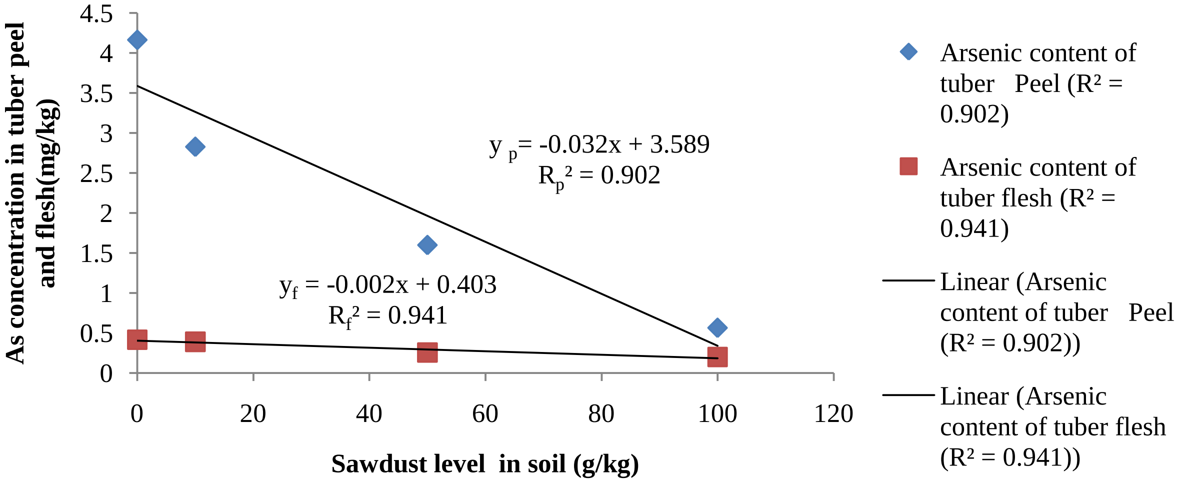
Table 17. Effect of As on As content of peel and flesh of potato tuber

Treatments	**As content in tuber peel**	**As content in flesh**
As_0	0.000 d	0 .000 d
As_1	1.780 c	0.225 c
As_2	3.511 b	0.2745 b
As_3	3.867 a	0.6236 a
LSD Value	0.1099	0.008426
CV (%)	5.25	6.66
Level of significance	**	**

[As_0, Control; As_1, 25 mg As kg^{-1} soil; As_2, 50 mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

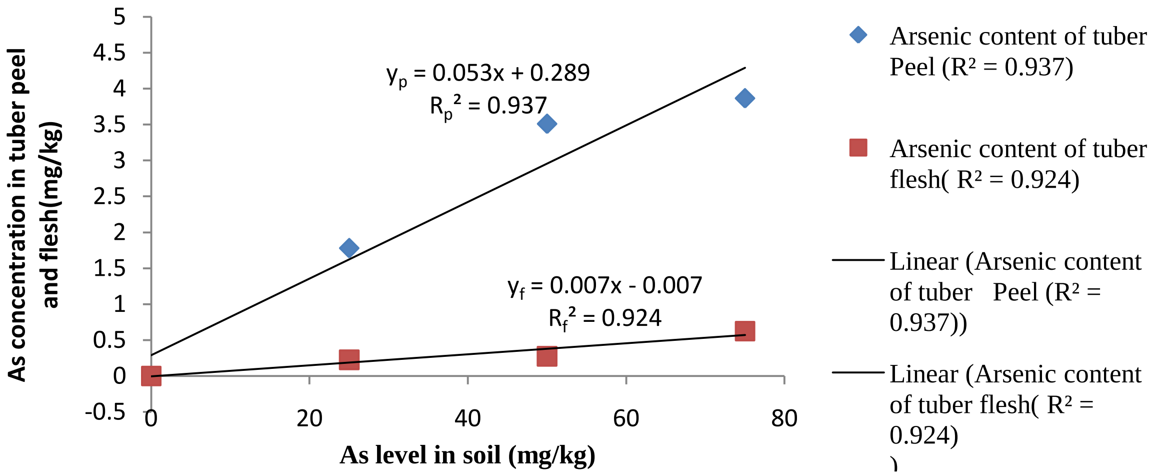
**, * Indicate 1% and 5% level of significance respectively

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



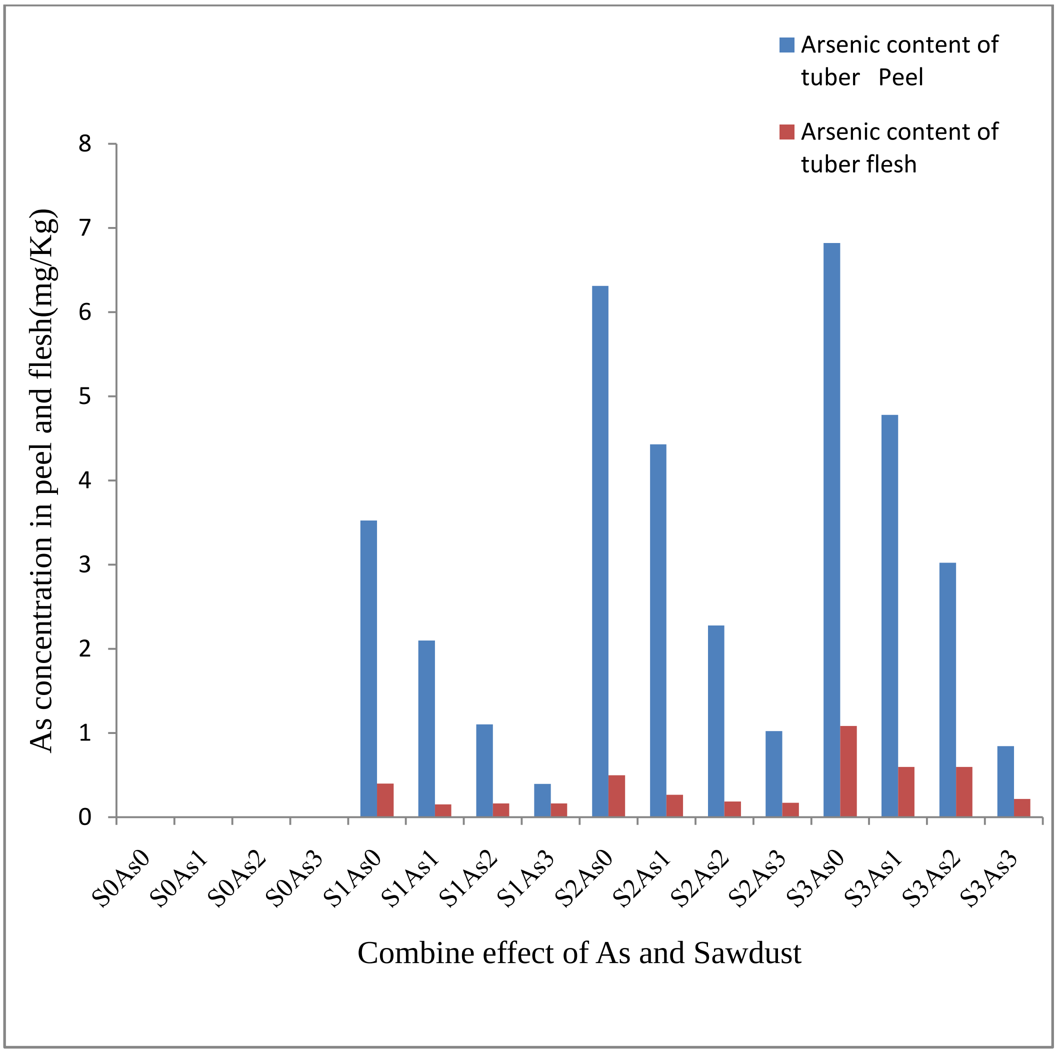
[S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 22. Linear relationship between sawdust and As content of tuber peel and flesh [LSD value = 0.09970 and 0.008426 in As content in tuber peel and flesh respectively]



[As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil]

Figure 23. Linear relationship between As level in soil and As content of tuber peel and flesh
[LSD value = 0.1099 and 0.008426 in As content in tuber peel and flesh respectively]



[As_0, Control; As_1, 25mg As kg^{-1} soil; As_2, 50mg As kg^{-1} soil; As_3, 75 mg As kg^{-1} soil and S_0, Control; S_1, 10 g sawdust kg^{-1} soil; S_2, 50 g sawdust kg^{-1} soil; S_3,100 g sawdust kg^{-1} soil]

Figure 24. Combined effect of sawdust and As levels on As content in potato tuber peel and flesh [LSD value = 0.1994 and 0.01685 in As content in tuber peel and flesh respectively]

According to above discussion on the basis of biosorption by bioasorbent (sawdust) a tentative layout of minimizing toxicity of As by biosoroption technology is given below.

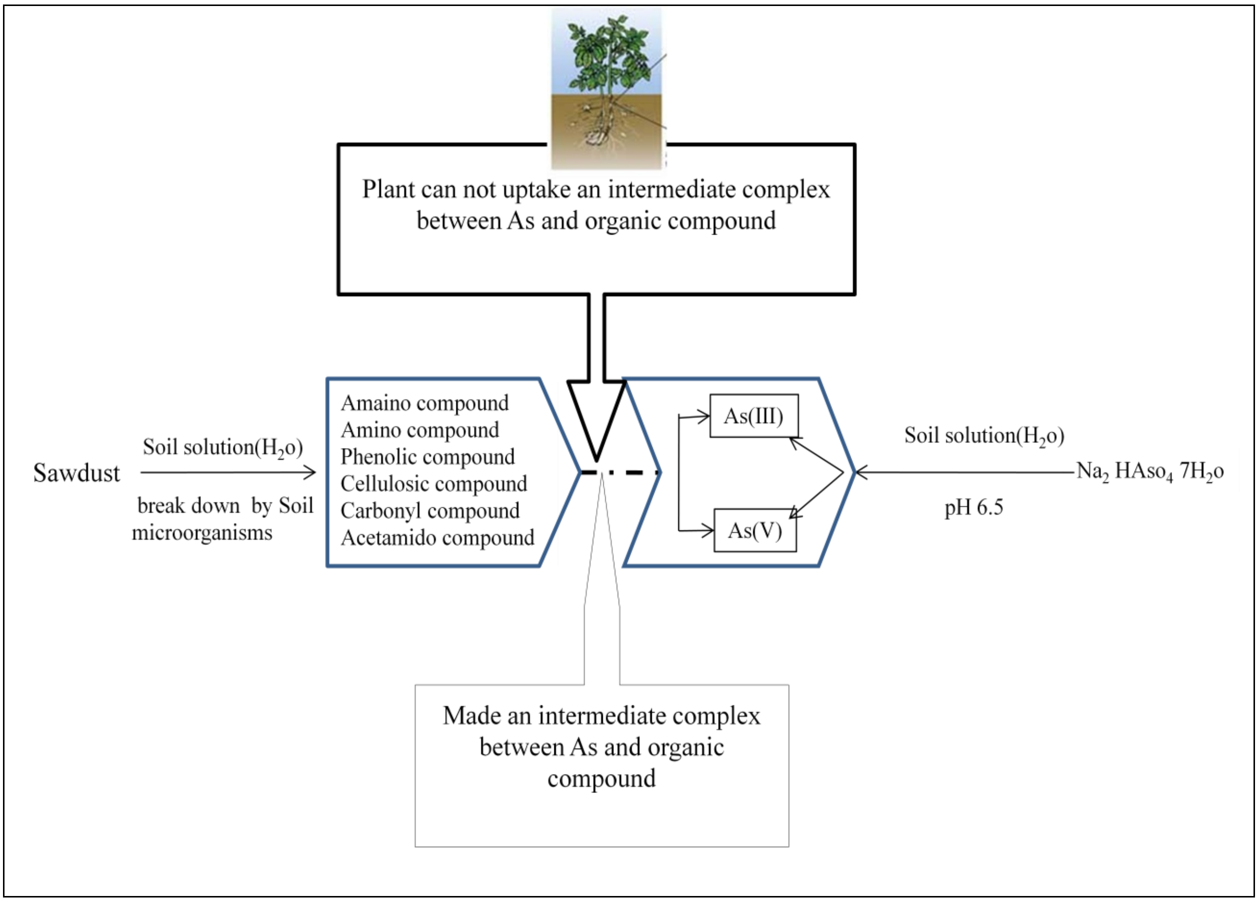


Figure 25. Tentative layout of minimizing toxicity of As by biosoroption technology

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 of treatments for the identification optimum level of sawdust for minimizing the toxicity of As from potato tuber in As contaminated soil and the best combination at Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka during period from 10th November 2012 to 18th February 2013. Two factor experiment included 4 Sawdust level viz., S_0 (Control), S_1 (10g kg^{-1} soil), S_2 (50g kg^{-1} soil), S_3 (100g kg^{-1} soil) and 4 As levels viz., As_0 (control), As_1 (25mg kg^{-1} soil) As_2 (50mg kg^{-1} soil), As_3 (75 mg kg^{-1} soil) was outlined in Complete Randomized Design (CRD) 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, chlorophyll content in leaf (%), days to maturity (visual observation) and dry matter content (%) of stem were recorded at different growth stages. Dry matter content (%) of tuber flesh and tuber peel, number of tubers $hill^{-1}$, tuber grade (% by number and weight), and tuber yield were recorded after harvesting. As content of tuber peel and flesh, total soluble solids in tuber (%), specific gravity of tuber. After harvesting collected data were statistically analyzed for the study of effects of sawdust and / or As on potato and evaluation of treatments for the identification of optimum sawdust level for minimizing the toxicity of As from potato tuber in As contaminated soil.

Results showed that sawdust had significant effects on growth yield and quality contributing parameters of potato. Sawdust improved the quality characters of potato tuber like As content of tuber peel and flesh. The soil treated with S_3 (100 g sawdust kg^{-1} soil) reduced 51.44% and 86.41% As accumulation through tuber flesh and peel, respectively compared to control (S_0). S_3 (100 gm sawdust kg^{-1} soil) was the best treatment for remediation of As toxicity from potato tuber. The highest specific gravity of tuber (1.039) was recorded in S_1

while, the minimum (1.013) was found from S_2. Sawdust made prolong days to emergence and days to maturity compared to control which kept negative role on some growth and yield parameters. The experiment showed that some growth and yield parameters viz., plant height, number of leaves plant^{-1}, leaf area, number of stems hill^{-1}, stem diameter, chlorophyll content in leaf (%), and number of tubers hill^{-1} and tuber yield decreased with increasing the sawdust levels. The tallest plant (42.83cm) was recorded in S_0 and the shortest (10.67 cm) was scored in S_3 treatment at harvesting stage. The maximum number of leaves (102.6) was recorded in S_0 treatment at 60 DAP whereas the minimum (39.25) was in S_3 treatment at 30 DAP. The maximum number (11.00) stems hill^{-1} was recorded at 45 DAP in S_0 where the minimum number (6.833), at 30 DAPS in S_3. The maximum number (49 cm^2) for leaf area, was recorded at 75 DAP in S_0 (control) whereas the minimum number (10.5 cm^2) was recorded at 30 DAP in S_3. The widest stem diameter (0.6183cm), was recorded at 75 DAP in S_0 (control) and the narrowest stem diameter was recorded at 30 DAP in S_3 (0.3483cm). The highest chlorophyll content in leaf (47.19%) was recorded in control (S_0) while, the minimum (39.42%) was found from $S_{3.}$ The highest tuber yield plant^{-1} (492.8) was recorded in control S_0 while the minimum (g 218.0) was found from S_3. The highest number of tuber plant^{-1} was recorded in control S_0 (17.42) while, the minimum was found from S_2 (9.25). Effect of As was significant on growth, yield and quality viz. stem diameter, number of tubers hill^{-1}, tuber yield, grade of tuber , As content of potato peel and flesh , total soluble solids content of tuber (%), specific gravity of tuber. Stem diameter decreased due to As compared to control where the widest stem diameter (0.595 cm), was recorded at 75 DAP in As_0 and the narrowest was recorded at 30 DAP in As_3 (0.393). The yield of tubers plant^{-1} decreased with increasing As levels. The highest tuber yield plant^{-1} (373.2 g) recorded from As_0 while the minimum was recorded in As_3 (304.4). As content in tuber peel and flesh was accelerated with increasing As levels in soil where the maximum sA hself rebut fo tnetnoc (0.6236 mg kg^{-1}) and peel (3.867 mg kg^{-1}) recorded from As_3 (75 mg As kg^{-1} soil) while no As accumulation found in control (As_0). The value of specific gravity increased up to S_1 (10 g sawdust kg^{-1}kg soil) and there after decreased with increasing sawdust levels. The highest value total soluble solids of tuber recorded from As_2 (1.35) while the minimum was in As_0 (1.13). In treatment combinations (As_2S_3) As content reduced to peel (1.023 mg kg-1) and flesh (0.150 mg kg-1). This result gives a chance to further research to study the accurate sawdust levels for minimizing 100% of As from potato tuber. Among the treatment combinations (As_1S_1) was suitable because in this combination, tuber flesh accumulated 0.15 mg kg^{-1} As which was lower than critical level of As contamination. So potato farmer can cultivate potato up to 25 mg kg^{-1} As contaminated soil using 10 g sawdust kg^{-1} soil. Potato production in this condition was safe for human consumption. Since As content in tuber reduced with increasing the sawdust levels the experiment opens the avenue for further research to find out the exact sawdust level to minimize 100% of As from potato tuber.

However, to reach a specific conclusion , more research on As contaminated soil is needed to be alone in different types of bioadsorbent with potato in As prone areas of Bangladesh for selecting suitable bioadsorbent with suitable dose to remideation of 100% As from potato. Considering above discussion further research can be done which are mentioned below

I. To study on the mechanism of different bioadsorvent viz., sawdust, egg shell, charcoal and oyster shell) in minimizing As toxicity from soil.
II. To study the As adsorption pathway form soil by using different biosorption technology.

Recommendation

Considering above result and discussion, it could be conclude that potato growers can produce their potato in 25 mg kg^{-1} contaminated soil treated with 10 g sawdust kg^{-1} soil since the product contain lower than critical level of As for human consumption .

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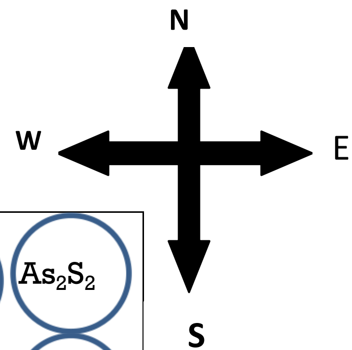
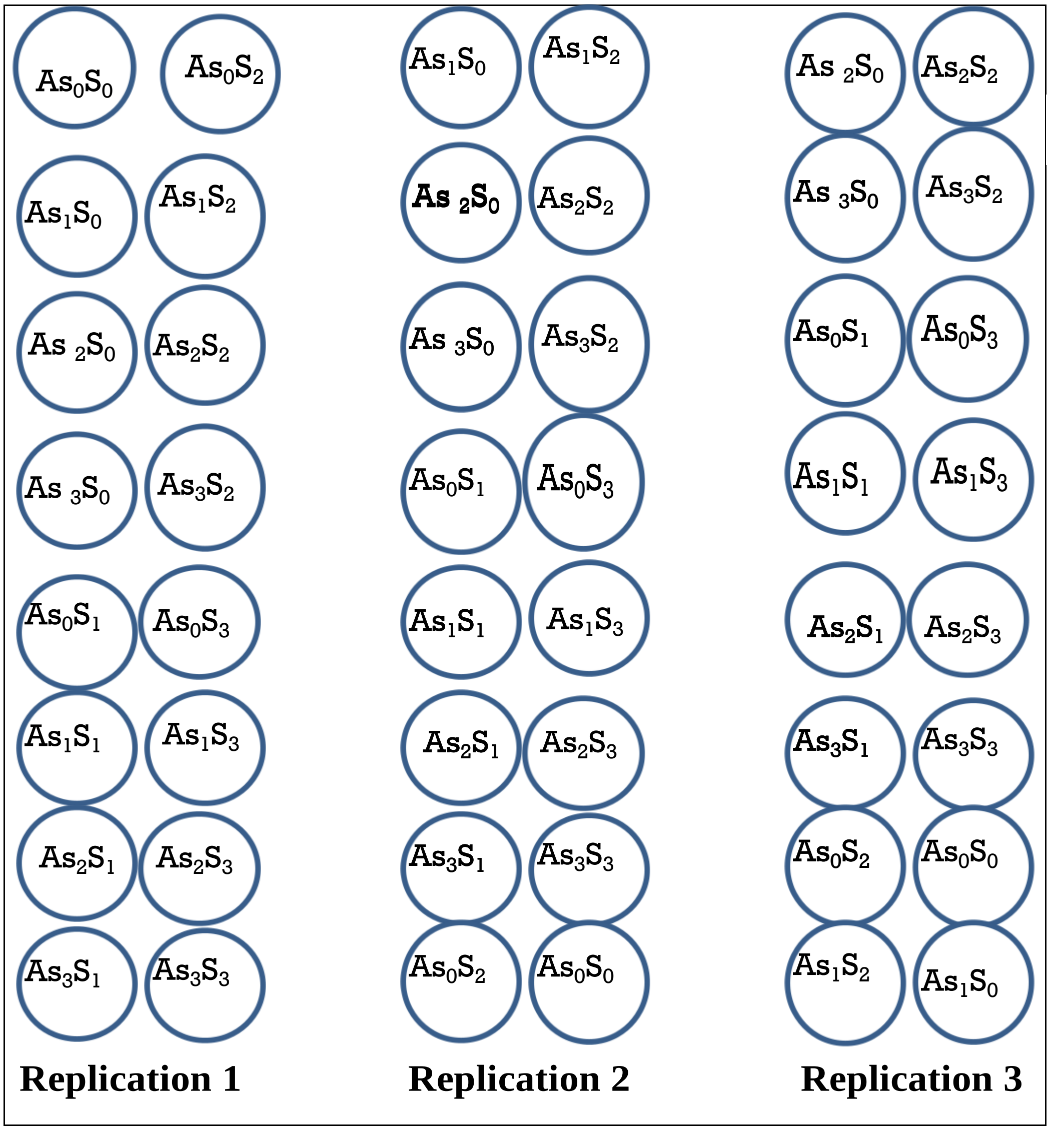
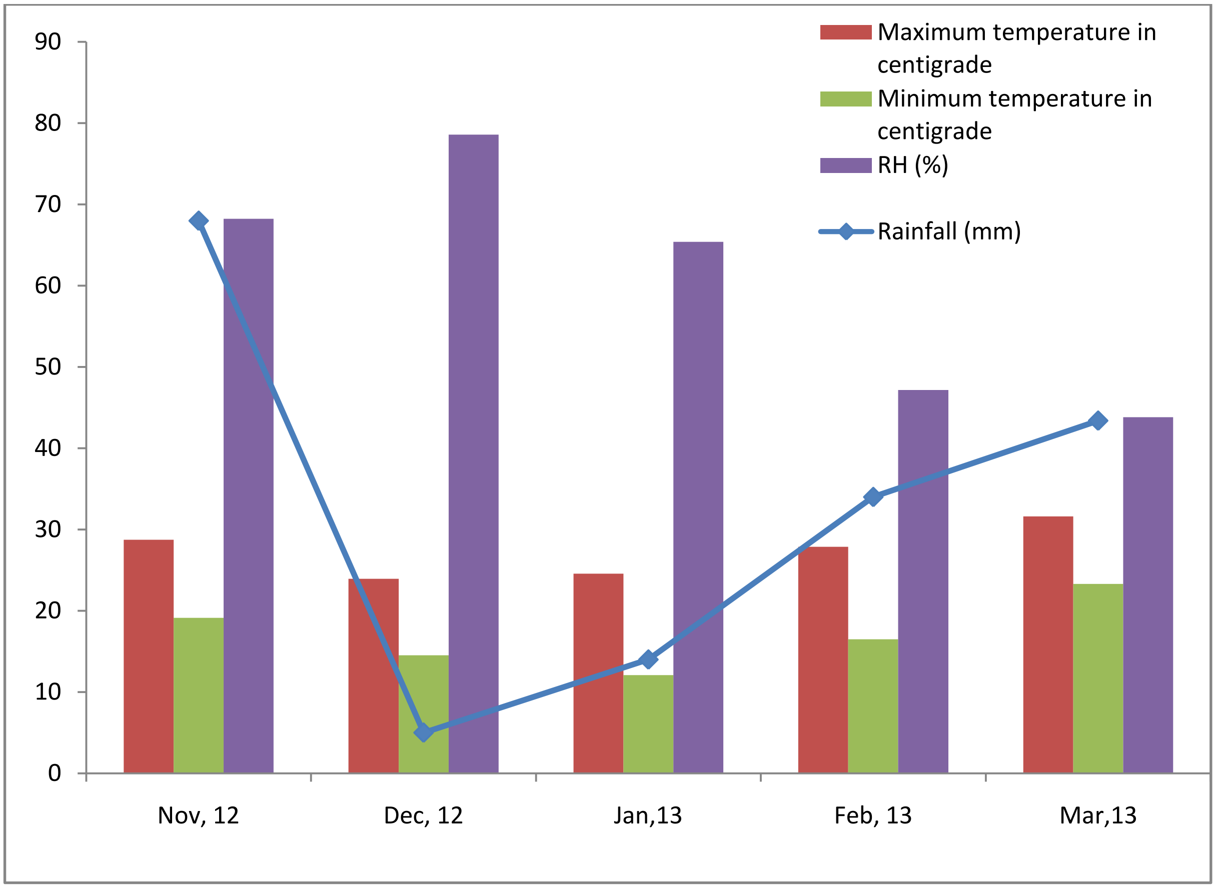
Appendix I. Lay out of Experiment





Sawdust level (Bioadsorbent):	**Arsenic levels:**
S_0- 0 g Sawdust kg^{-1} soil	As_0 – 0 mg As kg^{-1} soil
S_1-10 g Sawdust kg^{-1} soil	As_1 – 25 mg As kg^{-1} soil
S_2-50g Sawdust kg^{-1} soil	As_2 – 50 mg As kg^{-1} soil
S_3-100g Sawdust kg^{-1} soil	As_3 – 75 mg As kg^{-1} soil

Appendix II. Monthly average maximum and minimum temperature, Relative humidity and total rain fall for month November and December 2012, January, February and March 2013 in Sher-e- Bangla Agricultural University, Dhaka-1207 .



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

Source of Variation	Degrees of freedom (df)	Mean Square for Days requires to emergence	Mean Square for Days requires to maturity
Factor A	3	11.632*	8.167**
Factor B	3	7.465	7.389**
Interaction (A x B)	9	2.280**	1.741*
Error	32	2.875	0.729

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

Appendix IV. 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
Factor A	3	1041.583**	959.243 **	668.354**	462.021**
Factor B	3	66.806	18.965	19.854	16.910
Interaction (A x B)	9	15.120*	27.632*	24.113*	35.095*
Error	32	9.583	13.896	17.979	20.979

*: 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 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
Factor A	3	10586.500**	20084.299**	2471.611**	5958.132**
Factor B	3	465.833	305.465	256.833	169.410
Interaction (A x B)	9	174.556*	275.873*	133.630*	141.743*
Error	32	218.875	19.9	166.375	125.021

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

Appendix VI. 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
Factor A	3	34.52**	32.11**	32.11**	29.86**
Factor B	3	3.80	4.72	4.72	5.53
Interaction (A x B)	9	3.36*	5.75*	5.75*	5.95*
Error	32	3.77	4.54	4.542	4.54

*: Significant at 0.05 level of probability;

**: Significant at 0.01 level of probability

Appendix VII. 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
Factor A	3	946.812**	956.812**	946.812 **	752.196**
Factor B	3	38.251	38.251	38.251	22.452
Interaction (A x B)	9	194.320**	204.320**	184.320**	171.430**
Error	32	26.757	26.757	26.757	14.099

* Significant at 0.05 level of probability;

** Significant at 0.01 level of probability

Appendix VIII. 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
Factor A	3	0.092**	0.061**	0.105**	0.109**
Factor B	3	0.008*	0.060*	0.014*	0.015*
Interaction (A x B)	9	0.005*	0.009*	0.011*	0.011*
Error	32	0.004	0.311	0.006	0.008

*: 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 yield

Source of Variation	Degrees of freedom (df)	Mean Square for				
		Stem dry matter content (%)	Tuber flesh dry matter content (%)	Tuber peel dry matter content (%)	Number of tuber $plant^{-1}$	Yield of tuber $plant^{-1}$
Factor A	3	18.832*	14.466*	18.256*	175.410**	190347.0**
Factor B	3	4.289	4.519	5.342	19.299*	2929.121*
Interaction (A x B)	9	7.394*	2.021*	2.257*	13.021**	6213.403**
Error	32	4.078	2.799	3.449	0.507	1796.060

*: 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			
		Number of marketable tubers	Number of non marketable tubers	Weight of marketable tubers	Weight of non-marketable tubers
Factor A	3	100.447	100.768	119.753*	119.752*
Factor B	3	41.063	41.142	66.716	66.716
Interaction (A x B)	9	414.031*	413.875*	104.508*	104.508*
Error	32	236.559	236.467	70.690	70.690

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

Appendix XI. 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				
		Chlorophyll content in mature leaf	Specific gravity of tuber	Total soluble Sugar of tuber	As content of tuber peel	As content of tuber flesh
Factor A	3	130.399*	0.137**	1.403*	0.122**	0.280**
Factor B	3	7.591	0.152*	1.139*	0.558**	0.798**
Interaction (A x B)	9	21.714*	0.073*	0.986*	0.169**	0.070**
Error	32	31.177	0.002	0.265	0.001	0.000

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

Plates

Plate1. Overview of whole experiment

Plate 2. Leaf showed the yellow color due to toxicity of As

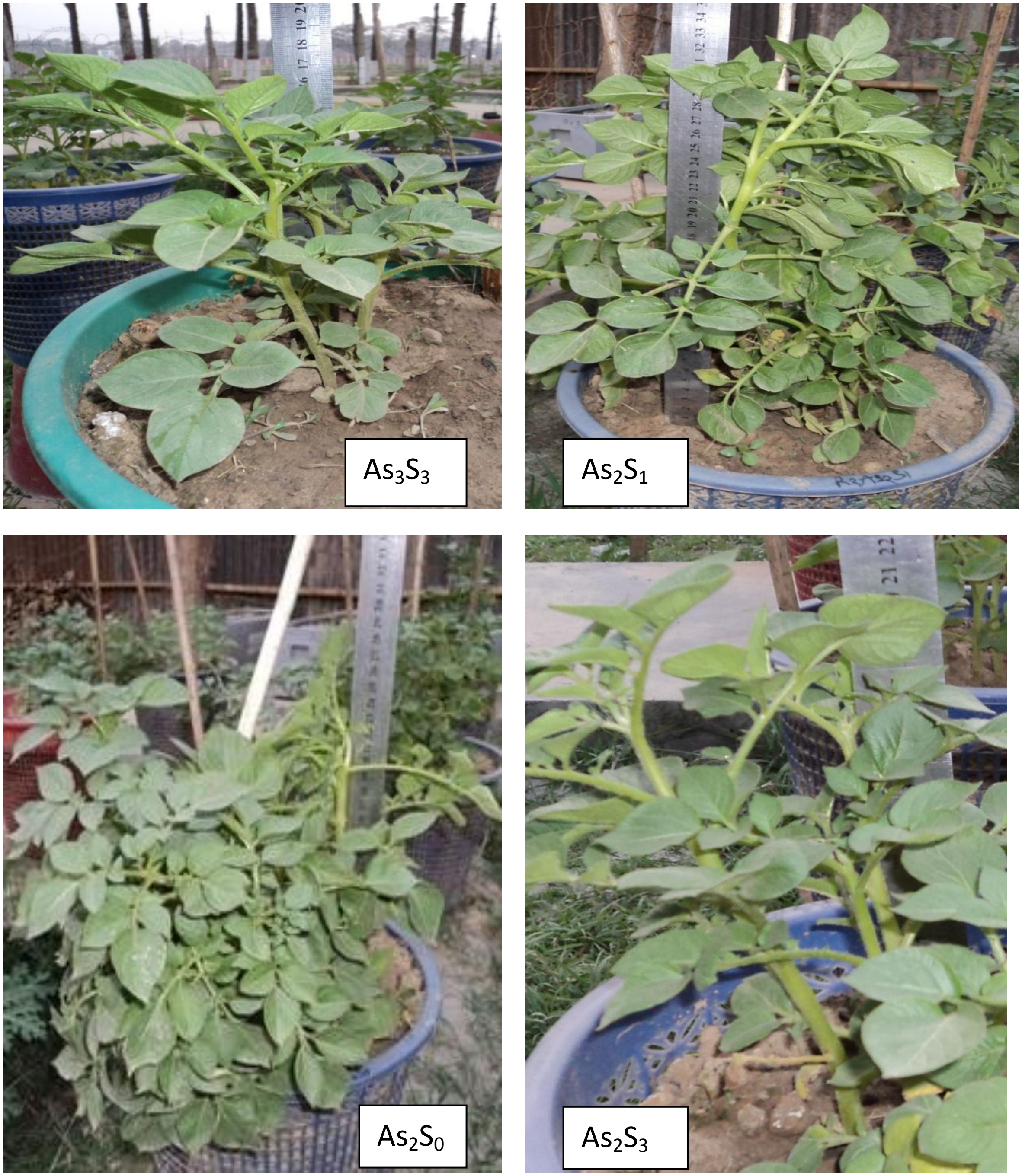


Plate 3. Comparison of plant height among different treatment

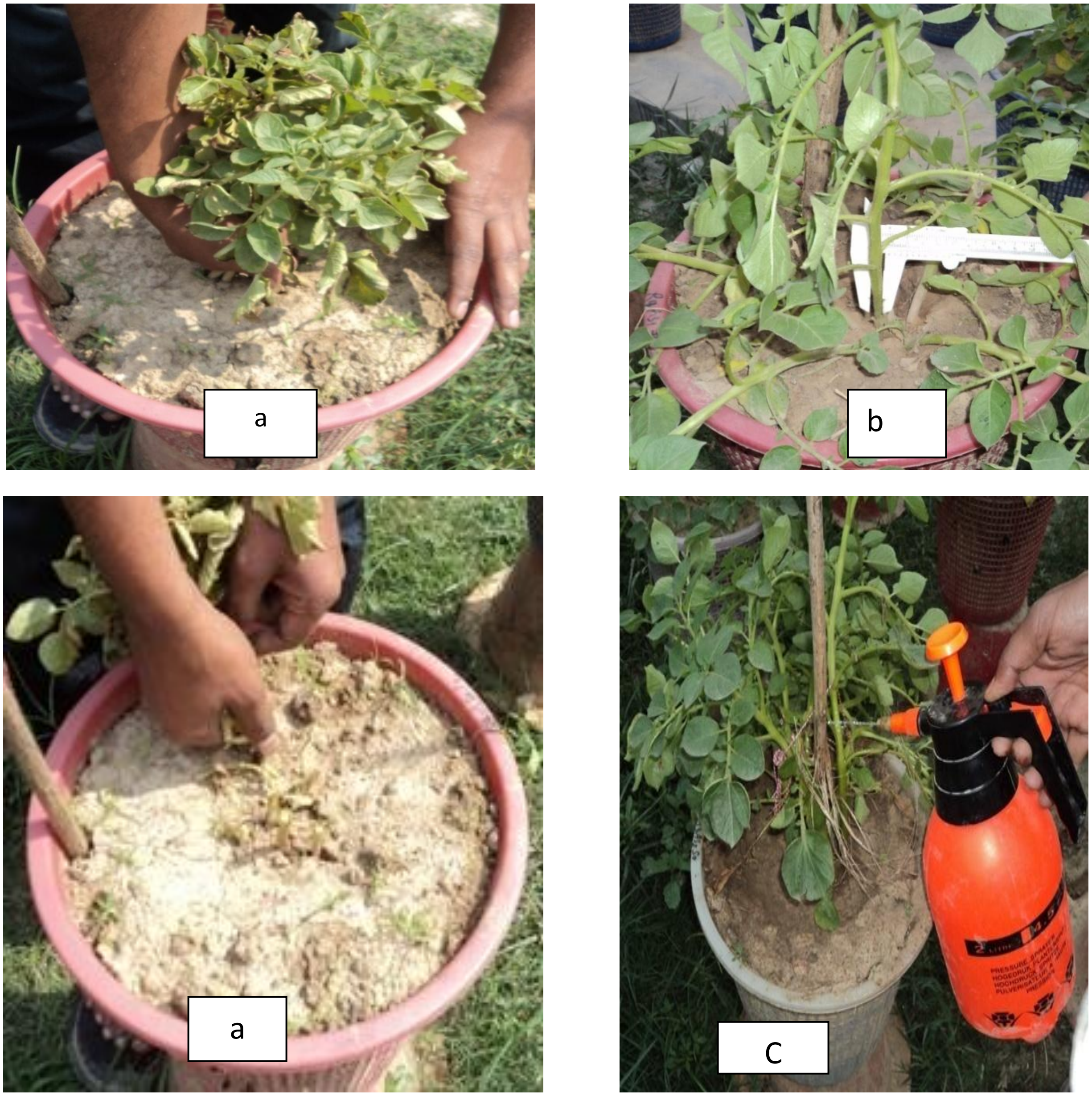


Plate 4. Haulm pulling (a), controlled irrigation(c) and measurement of stem diameter by slide calipers (b)

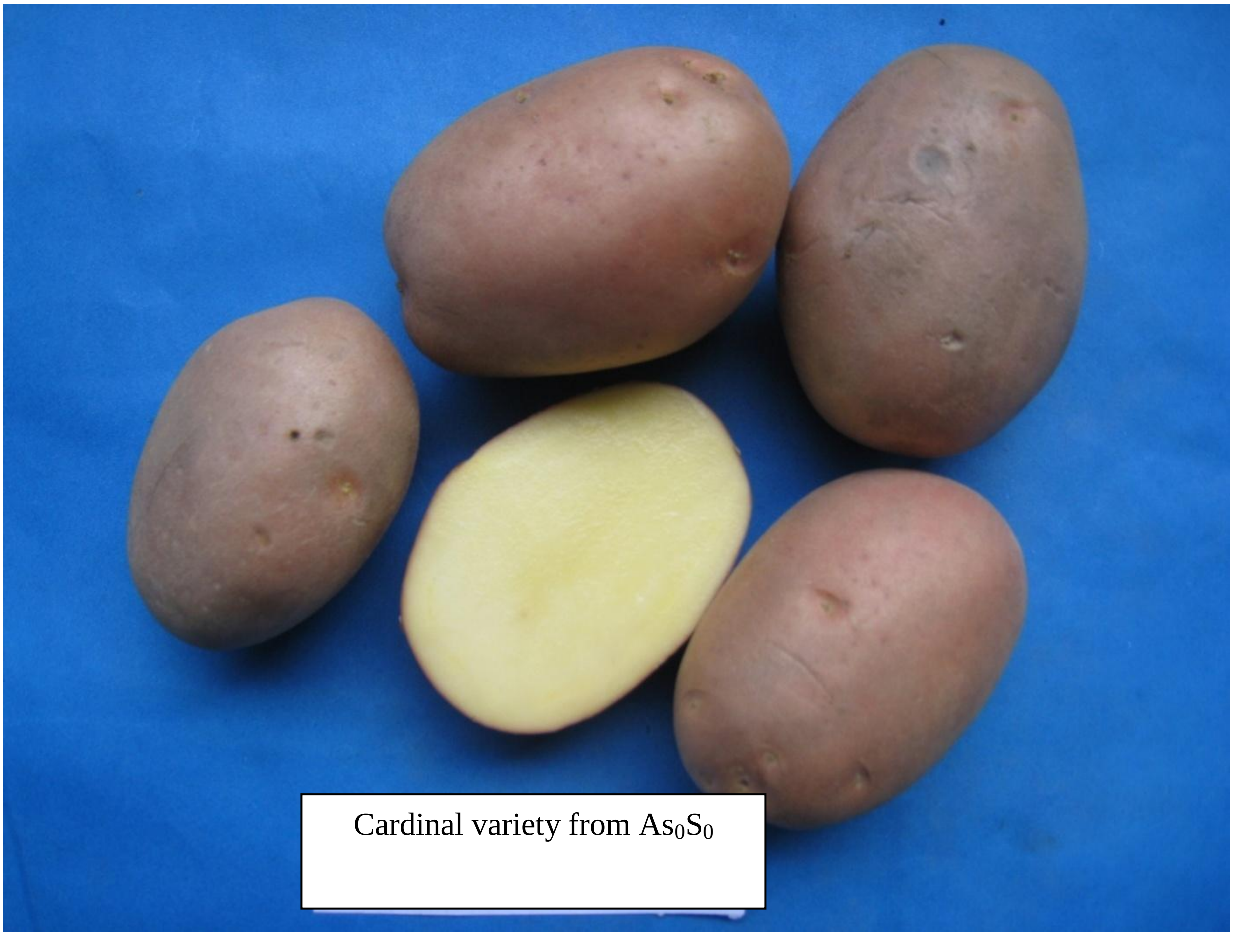


Plate 5. Harvested potato tuber