EFFECT OF POTASSIUM SOURCES AND VERMICOMPOST LEVEL ON YIELD AND PROCESSING QUALITY OF POTATO

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CERTIFICATE

This is to certify that the thesis entitled '**Effect of Potassium Sources and Vermicompost Level on Yield and Processing Quality of Potato**' submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY**, embodies the results of a piece of bona fide research work carried out by **AKHI BADRUNNESA**, Registration No.**13-05589** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from the period of November, 2018 to February, 2019 to assess the effect of potassium sources and vermicompost level on yield and processing quality of potato. The potato variety BARI Alu-25 (Asterix) was used as test crop for this experiment. The experiment consisted of two factors: Factor A: Potassium sources (3 sources) as- K_1: KCl, K_2: KNO_3, K_3: K_2SO_4; Factor B: Levels of vermicompost (4 levels) as - Vm_0: 0 ton vermicompost ha^{-1}, Vm_1: 4 ton vermicompost ha^{-1}, Vm_2: 8 ton vermicompost ha^{-1} and Vm_3: 12 ton vermicompost ha^{-1}. The two factor experiment was laid out in a split-plot design with three replications. Most of the recorded data on different yield attributes, yield and quality of potato showed significant variations for different sources of potassium and levels of vermicompost; and their combined effects were also significant. Highest yield of potato tubers (27.86 t ha^{-1}), dry matter content (19.83%), specific gravity (1.090) and starch (14.81%) was recorded from K_2SO_4, whereas, the lowest was found from KNO_3. Number of tubers $hill^{-1}$, average tuber weight, yield, different categories of potato tuber, firmness, dry matter content, specific gravity, starch and vitamin-C content increased with increasing the vermicompost level. A negative relation was observed between TSS and sugar content. In respect of the combined effect, the highest yield of potato tubers (31.17 t ha^{-1}), dry matter content (21.12%), specific gravity (1.103) and starch (16.34%) was found from K_3Vm_3, whereas, the lowest was recorded from K_2Vm_0. However, K_1Vm_2, K_1Vm_3, K_3Vm_2 and K_3Vm_3 showed statistically similar results in yield and quality attributes. So,K_2SO_4 or KCl as a source of potassium and 8 or 12 ton vermicompost ha^{-1} showed excellent performance. But availability of potassium sources and economic point of view, KCl combined with 8 ton of vermicompost ha^{-1} could be used for the production of quality potato in Bangladesh.

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Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Potato (*Solanumtuberosum* L.) belongs to the family Solanceae is the fourth-largest world food crop after rice, wheat, and maize (Ahmed, *et al*., 2017; Chakraborty *et al*., 2010; Haas *et al*., 2009). The large per capita consumption can be easily justified because they are rich in carbohydrates, minerals but also contain a large amount of high quality of proteins, vitamin C and minerals (Brown, 2005). Potato is one of the major vegetable crops cultivated throughout the southern Mediterranean, with Spain and Italy being the main producers, with 2.0 and 1.3 million tons of annual tuber production, respectively (FAOSTAT, 2018). In Bangladesh, the total acreage, production and yield of potato is 0.48 million hectares, 0.974 crore MT and 20.41 t ha^{-1}, respectively and the yield of potato is comparatively low in comparison with the other major potato producing countries *viz*., USA (47.15 t ha^{-1}), France (54.19 t ha^{-1}) (FAOSTAT, 2018). The main reasons for the low yield include the use of poor quality seed tubers and inefficient management practices including planting time and spacing.

Potato crop is highly responsive to fertilization, which can be attributed to high production potential, short cycle and relatively superficial root system. However, due to the high potential of response to fertilization, the use of large amounts of fertilizer per unit area has been verified (Silva *et al*., 2018). Potato cultivation is quite demanding in inorganic nutrients and adequate organic fertilization is a key factor for maximizing yield of potato and producing tubers of high quality (Petropoulos *et al*., 2020). There is an increased interest from potato growers in defining the optimal fertilization regimes in order to maximize total yield, while at the same time minimizing the production cost and maintaining high quality (Fontes*et al*., 2016). Potato yields and tuber quality depend on different factors, such as soil and climatic conditions, agricultural techniques, biological and cultivar specifics, etc. Rational use of fertilizers and manures, ensured 30-50% yield increase of good quality while preserving soil fertility.

Potato cultivars have different strategies for dealing with potassium (K) deficiency in soil, and their response to different forms and rates of K fertilization may vary because of differences in soil K availability (Yakimenko and Naumova, 2018). A number of research has been devoted to studying the effect of type, rates and forms of fertilizers on potato tuber yields and quality (Davenport and Bentley, 2001; Ewais *et al.*,2010; Zorb *et al.*, 2014). Potassium influences both quantity and quality of potatoes (Karam *et al.*, 2011; Lakshmi *et al.*, 2012) through various mechanisms such as enzyme activation, stomatal conductance, photosynthesis, protein synthesis, and transport of sugars and starch (Werij *et al.*, 2007). Various sources of K salts are used for plants nutrition such as potassium chloride (KCl), potassium sulfate (K_2SO_4), mono potassium phosphate (KH_2PO_4), potassium nitrate (KNO_3) and potassium silicate ($K_2O.4SiO_2$) (Magen, 2004). Among them potassium silicate ($K_2O.4SiO_2$) caused very good results to improve the growth and yield of plants (Salim *et al.*,2011; Rytel *et al.*, 2013; Salim, 2014).

Vermicompost, the excreta of earthworm, can improve the health and nutrients of the soil and is better compared to other traditional compost (Joshi *et al.*, 2015). Vermicomposting is one of the biological process in which the organic wastes has been converted into nutrient rich manure by the action of earthworms. The characteristic feature of vermicompost such as high porosity and moisture holding capacity increases the growth of plants (Yadav and Garg, 2019). It has 1.5-2.2% nitrogen (N), 1.8-2.2% phosphorus (P), and 1.0-1.5% potassium (K) on average with organic carbon is between 9.15 and 17.98%, and has micronutrients such as sodium (Na), calcium (Ca), zinc (Zn), sulphur (S), magnesium (Mg), and iron (Fe) (Adhikary, 2012). It helps with soil water retention, regulation of soil temperature and structure, enhances the soil with nutrient elements, and increases the biomass and community structure of the microbial population (Vivas *et al.*, 2009). Vermicompost used as a fertilizer and soil conditioner (Rajesh *et al.*, 2003; Munroe, 2007, Borah *et al.*, 2007) and responsible for the improvement of the soil physical properties and also ensure the supply of vital plant nutrients (Nardi *et al*., 2002; Klavins *et al*., 2004, Smith *et al*., 2014).

The quality of potato tubers and their chemical composition are influenced by many factors - genetics, soil fertility, weather conditions and applied nutrients (Rytel *et al*., 2013). Potassium deficiency is observed the plants are short, leaves become pale-green and later in the vegetation at leaves ends and tops they become necrotic (Kerin and Berova, 2008; Kumar and Sharma, 2013). Potassium application resulted in higher leaf area, increased plant height, prolonged bulking duration, enhanced tuber size, and a higher proportion of medium and large size grades and higher yields (Trehan *et al*., 2001). Potassium also affects dry matter percentage, increases ascorbic acid content, decreases reducing sugars, phenol contents, and enzymatic degradation (Chen *et al*., 2004; Werij *et al*., 2007). Many potato producers for fry industry changed from the use of potassium chloride to potassium sulfate, as there is a concept that the use of this source improves tuber quality (Silva *et al*., 2018). On the other hand, application of vermicompost increased seed germination, stem height, number of leaves, number of stems, leaf area, leaf dry weight, root length, root number, single tuber weight, total yield, number of tubershill^{-1}, chlorophyll content, TSS of juice, micro and macro nutrients, carbohydrate (%) and protein (%) content and improved the quality of the tubers (Theunisen *et al*., 2010; Joshi *et al*., 2014).With this background and situation the present study was conducted to fulfill the following objectives:

1. To study the effect of potassium sources and levels of vermicompost for maximizing yield with good quality of potato.
2. To find out the optimum combination of potassium source and vermicompost level on yield with good quality of potato.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Potato is a crop of major significance in human nutrition, ranking fourth in food production, after wheat, maize, and rice. This crops demand high investment in fertilizers, and depending on price and growing season, it can account for more than 30% of total crop production cost. Therefore, there is a need to develop fertilizer management strategies for potato, increasing the efficiency of fertilizer use. Organic and inorganic fertilizer management is the important factor that greatly affects the growth and yield of potato. Among different Organic and inorganic potassium and vermicompost play an important role for the yield and quality of potato. However, very limited research work have been conducted on the performance of potato in response to potassium source and vermicompost in various part of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect reviewed in this chapter under the following headings:

2.1 Effect of potassium sources on growth and yield of potato

The influence of potassium fertilizer source (K_2SO_4 and KCl) on potato yield and quality under pot experimental conditions was studied by Manolov *et al.* (2005) at the Agricultural University, Mendeleev, Bulgaria. Experiments included increasing rates of the potassium fertilizers providing 200, 400 and 600 mg kg^{-1} soil K_2O and K_2SO_4 and KCl were the sources. Data indicated no statistical differences in potato yield as a result of potassium fertilizer sources. In contrast, all studied quality parameters with the except for reducing sugars were influenced by potassium sources. Increasing rates of KCl decreased most severely dry matter, starch and vitamin C contents in potato tubers which were diminished with 15%, 46% and 50% by potassium 600 treatment, respectively when compared to control.

An experiment was conducted by Gunadi (2009) to determine the response of potato to potassium (K) fertilizer sources and application methods in Andisols of West Java was conducted at a farmer's field in the highland area of Pangalengan, West Java. The treatments consisted of two K fertilizer sources (potassium chloride-KCl and potassium sulphate-K_2SO_4), two K rates (150 and 250 kg K_2O ha^{-1}), and three application methods (single, split, and split combined with foliar application). In the single application treatment, K was applied at planting, while in the split application treatment the K was applied half rate at planting and the rest at 6 weeks after planting (WAP). In the split combined with foliar application treatment, the K fertilizer was applied half rate at planting, a quarter rate at 6 WAP and another quarter rate by foliar spraying at 7, 8 and 9 WAP. The results showed that plant height was not significantly affected by the treatment. However, the sources and application methods of K fertilizer affected canopy cover, crop cover weeks (CCW), tuber dry weight (DW), and total plant DW at 10 WAP. Potatoes supplied with K_2SO_4 either in split or split combined with foliar application had significantly higher percent canopy cover, CCW, tuber DW, and total plant DW than those supplied with K fertilizer in single application. Potatoes supplied with K_2SO_4 had a higher tuber yield compared to those fertilized with KCl, especially under split or split combined with foliar application. To attain the same level of tuber yield as in the split combined with foliar application method, the rate of K_2SO_4 should be increased from 150 to 250 kg K_2O ha^{-1} when using single application. It is therefore suggested that K_2SO_4 for potatoes should be used in split application combined with foliar application.

Salim *et al*. (2014) conducted two field experiments to study the effect of foliar spray with potassium nitrate, potassium silicate, potassium chloride and mono potassium phosphate at the rates 1000 ppm and 2000 ppm on growth, yield parameters and some biochemical constituents of potato plant. Two samples were taken after 65 days from sowing and at harvest. At the 1st sample date, plant length, shoot fresh weight, shoot dry weight, total chlorophyll reading, total nitrogen and proteins, P, K, Mg, Fe, Mn and Zn concentrations (in potato leaves) were determined. At the 2nd sample date (harvesting stage), tubers number per plant, tubers weight/plant, yield/plant and yield/plot were recorded. The higher rate of potassium silicate and potassium nitrate were more effective than the rest treatments on enhancing the vegetative growth parameters and yield components. In general, all potassium treatments have strongly stimulating effect on mineral nutrients (N, P, K, Mg, Zn, Mn and Fe) and protein concentration of potato leaves in both seasons.

Neshev and Manolov (2016) carried out a field experiment included two fertilizer rates - 100 and 200 kg K_2O ha^{-1} supplied as K_2SO_4 or KCl. Increased content of nitrogen in roots at variants fertilized with KCl was observed 3.01% for KCl (100) and 3.13% for KCl (200). Potassium fertilization have no effect on seedling emergence but increased K content in roots compared to control. The N content in aboveground biomass was the lowest for KCl (100) (4.13%) and for KCl (200) (3.84%). The applied potassium fertilizers increased K content in aboveground biomass compared to control. The high KCl rate at variant KCl (200) increased K content in aboveground biomass up to 5.16%. The fertilization with K_2SO_4 led to slight decrease of N content in the tubers compared to control (2.32%), but he KCl increased tuber N content from 2.60% at variant KCl (100) to 2.89% at KCl (200). The K content in tubers was not considerably influenced by the fertilization but an exception was observed for variant KCl (200) where it (2.70%) exceeded the one at the other variants.

A field experiment was conducted by Mohan *et al*. (2017) at KVK Kandali, UAS, Bengaluru to study the effect of different rates and sources of potassium on growth, yield and quality of potato. Results revealed that highest growth parameters like plant height (49.0), number of branches (2.83), and total dry matter production (6366.04 kg ha^{-1}) recorded with application of 75:75:175 kg ha^{-1} NPK with K as Bio K + Sulphur (S). Significantly lower growth parameters like plant height (31.67), number of branches (1.99), and total dry matter production (2063.02 kg ha^{-1}) recorded in control. Number of tuber and tuber weight per plant were significantly higher due to application of 75:75:175 kgha^{-1} NPK with K as Bio K + S (4.80 and 560.67) and was on par with 75:75:175 kg ha^{-1} NPK with K as SOP + Sulphur (4.6 and 545.67). Maximum tuber yield was recorded with 75:75:175 kg ha^{-1} N P K with K as Bio-K+ S (31.15t ha^{-1}) and significantly lower tuber yield recorded in absolute control (11.0). Significantly highest protein (8.50%) and starch (79.27%) content were recorded in treatment 75:75:175 kgha^{-1} NPK with K as Bio K + S. Total N, P, K content in haulm (1.35, 0.27 and 2.87) and tuber (1.34,0.43 and 1.75) was significantly higher due to application of 75:75:175 kg ha^{-1} NPK with K as Bio-K + S and was on par with application of 75:75:175 kg ha^{-1} NPK with K as SOP+S. As regard to micronutrients, significantly higher Fe, Mn, Zn Cu and B content in haulm (277.63, 152.41, 44.54, 32.85 and 9.82) and tuber (147.06, 53.6, 12.37, 26.65 and 16.53) was recorded due to application of 75:75:175 kgha^{-1} NPK with K as Bio K + S. B:C ratio of 4.74 was recorded with the application of (75:75:175 kg ha^{-1} NPK) K as Bio K + Sulphur is found to be more profitable compared to other treatments in potato cultivation.

Mello *et al*. (2018) conducted an experiment to evaluate PH (Polyhalite is a hydrated sulfate evaporite mineral containing potassium) as a fertilizer for potato production in the weathered tropical soils in Brazil with either muriate of potash (MOP), sulfate of potash (SOP), or PH as the K source; with kieserite and gypsum added to the SOP to make a synthetic PH with similar composition; P either as single super phosphate (SSP) for the MOP blend or mono ammonium phosphate (MAP) for the PH and SOP blends; and N as urea adjusted for the N in MAP. All were applied at four application rates of 62, 125, 187, and 249 kg K ha^{-1} and a control was also included consisting of N and P as urea and MAP but no K, Ca, Mg, or S. Findings revealed that the potato yields increased linearly with increasing K application rate from 22.4 t ha^{-1} for the control to the highest yield of 29.2 t ha^{-1} and were higher for PH and SOP than MOP (28.8, 29.2, and 25.3 t ha^{-1}, respectively). Polyhalite blend increased dry matter and starch at the higher application rates compared with MOP and SOP at Tapira and increased potato hardness and crunchiness at the optimum 62 kg K ha^{-1} application rate at Casa Branca. Yield response was similar for PH and SOP but quality differences between these two fertilizer blends were observed even though they were similar in composition.

Yakimenko and Naumova (2018) conducted a study was performed to evaluate the effect of K fertilization rates (0, 30, 60, 90, 120 and 150 kg K ha^{-1}) on tuber yield and quality (dry matter, starch, sugar and ascorbic acid content, taste) of two potato cultivars (Roco and Rosara) grown in the micro plot field experiment on Luvisol in the forest-steppe zone in southern West Siberia, Russia. The tuber yield of both potato cultivars increased with increase in K application rate up to 2.1 and 2.9 kg m^{-2} for Roco and Rosara, respectively. Sugar content, averaging 3.5%, was mostly determined by cultivar; however, in both cultivars it tended to decrease with increasing K application rate. The application of K fertilizer in the form of sulphate as compared to chloride increased dry matter content from 22.4 to 23.8% and ascorbic acid content from 13.2 to 14.6 mg100 g^{-1} fresh mass. Potassium application rate did not affect Roco tubers' taste, while improving Rosara tubers' taste under moderate application rates. The results underscore the importance to adjust fertilizer recommendations concerning potassium application rates and source on the basis of biological requirements and intended utilization of individual potato cultivars.

Silva *et al*. (2018) conducted an experiment to evaluate the effect of these two potassium sources on yield, specific gravity and chip color of potato chipping cultivars on a Dystrophic Red Latosol, in Canoinhas, Brazil. Treatments consisted of two potato cultivars, BRSIPR Bel and Atlantic, and two sources of potassium, chloride and sulfate, applied in the furrow at the planting time, in rates based on soil analysis. 100 days after planting each sub-plot was evaluated for yield, specific gravity and chip color and observed that there was no significant effect of potassium source on yield components, specific gravity and chip color of BRSIPR Bel and Atlantic.

2.2 Effect of vermicompost on growth and yield of potato

Sood and Sharma (2001) was carried out a field experiments at Shimla for assessing the utility of growth promoting bacteria, *Azotobacter* and Vermicompost for potato production indicated 'that *Bacillus cerus*(A) and *Bacillus subtilis* (B) separately increased the tuber yield of potato from 115 to 268 q ha^{-1} par with 100% NPK treatment. Vermicompost @ 5 t ha^{-1} increased the tuber yield by 34 to 65 qha^{-1}. The increase in yield was more when optimum NPK dose of fertilizer was applied. Inoculation of seed tubers with *Azotobacter* in the absence of N increased the tuber yield by 68 q $ha^{-1}$and the effect of *Azotobacter* decreased gradually as the dose of N was increased.

Alam *et al.* (2007) conducted an experiment to study the effect of vermicompost and NPKS fertilizers on growth and yield of potato (cv. Cardinal) in Level Barind Tract (AEZ-25) soils of Bangladesh. The organic matter of the experimental field soil was very low and in case of N, P, K and S also low. The treatments were, control, vermicompost (VC) 2.5 t ha^{-1}, VC 5.0 t ha^{-1}, VC 10.0 t ha^{-1}, VC 2.5 t ha^{-1}+50% NPKS, VC 5 t ha^{-1} + 50% 6 7 8 9 NPKS, VC 10 t ha^{-1}+50% NPKS, VC 2.5 t ha^{-1}+100% NPKS, VC 5 t ha^{-1}+100% NPKS, VC 10 t ha^{-1} +100% NPKS. The doses of N-P-K-S were 90-40-100-18 kg ha^{-1} for potato. Application of 10 t ha^{-1}vermicompost and NPKS significantly influenced the growth and yield of potato. The treatment produced the highest (25.56 t ha^{-1}) tuber yield of potato. Application of various amounts of vermicompost (2.5, 5, 10 t ha^{-1}) with NPKS fertilizers (50% and 100%) increased the vegetative growth and yield potato. Vermicompost at 2.5 5 and 10 t ha^{-1} with 50% of NPKS increased tuber yield over control by 78.3, 96.9 and 119.5 t ha^{-1}, respectively and vermicompost at 2.5, 5 and 10 t ha^{-1} with 100% of NPKS increased tuber yield by 146.8, 163.1 and 197.9%, respectively. The results indicated that vermicompost (10 t ha^{-1}) with NPKS (100%) produced the highest growth and yield of potato.

Ansari (2008) carried out a study to find out the effect of vermicompost application in reclaimed sodic soils on the productivity of potato (*Solanum tuberosum*), spinach (*Spinaci aoleracea*) and turnip (*Brassica campestris*). The soil quality was monitored during the experiment followed by productivity. The treatments were 4, 5 and 6 t ha^{-1} of vermicompost as soil application in plots already reclaimed by Vermitechnology. Among the different dosages of vermicompost applied there has been a significant improvement in the soil quality of plots amended with vermicompost @ 6 t ha^{-1}. The overall productivity of vegetable crops during the two years of the trial was significantly greater in plots treated with vermicompost @ 6 t ha^{-1}. The present investigation showed that the requirement of vermicompost for leafy crops like spinach was lower (4 t ha^{-1}), whereas that for tuber crops like potato and turnip was higher (6 t ha^{-1}).

Shweta and Sharma (2011) was conducted an experiment with the application of organic manures along with chemical fertilizers and recorded a significant effect on the tuber and haulm yield. Highest tuber (30.46 t ha^{-1}) was recorded with application of 100% NPK + 25 t ha^{-1} vermicompost and was significantly higher over sole use of chemical fertilizers. Tuber yield of potato recorded under 100% of recommended dose of NPK without organics (21.39 t ha^{-1}) was at par with 25 t FYM ha^{-1} or 12.5 t $VCha^{-1}$ applied along with 75% of recommended dose of NPK thereby, indicating a saving of 25% in NPK.

Mojtaba *et al.* (2013) conducted an experiment on which experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels 0 (control), 4.5, 9, and 12 t ha^{-1}). Results illustrated that the highest amount of plant height, number of stems, leaf and stem dry weight, Leaf Area Index (LAI), fresh and dry weight of tuber, total tuber weight, total number of tuber, tuber diameter, nitrogen percent of tuber, potassium percent of tuber and phosphorous percent of tuber were found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application at the rate of 12 t ha^{-1}promoted all above traits except days to seedling emergence, plant height in compared to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield compared with nitrogen and/or vermicompost alone treatments. To gain highest yield and avoidance of environments pollution use of 150 kg N ha^{-1} and vermicompost application of 12 t ha^{-1} are suggested.

Shirzadi (2015) conducted an experiment in order to evaluate the use of organic fertilizers (Vermicompost and Chicken manure) on the plant's height and number and weight of micro tuber Marfona cultivator potato (diameter of 25 to 35mm) with 2 factors of vermicompost in 4 levels (0,3,6 and 9 t ha^{-1}) and chicken manure in 4 levels (0,10,12 and 14 t ha^{-1}). The result showed that with the increasing Vermicompost fertilizer, plant height also increased. Also highest number and weight of tubers with a diameter of 25-35mm belonged to 12 tons Chicken manure treatment without Vermicompost.

Vojevoda *et al*. (2017) carried out an experiment to evaluate the effect of different application methods (seed tuber treatment and foliar application) of commercially-produced peat and vermicompost extracts on nutrient uptake in tubers and yield of potato using field experiments in organic farming system with potato variety ‘Borodjanskij Rozovij’. The tested extracts from the organic products included: peat extract (K45) and vermicompost extract (B45) obtained at + 45^{0}C by cavitation. The investigation was carried out at Stende Research Centre (Institute of Agro-resources and Economics). The chemical composition (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) of potato tubers was determined. The application of organic extract from vermicompost had a stimulating effect on mineral nutrient as N, P, K, Mg, and S accumulation in potato tubers, but 50% of cases showed reduction in Ca and Cu content that could influence the storage of tubers. The use of peat extract was significantly effective when the tubers were treated before planting. On average, tuber treatment and foliar spray with organic extracts contributed to 10% of tuber yield increase.

Hindersah *et al*. (2019) conducted a field experiment to obtain information on the effect of vermicompost with and without NPK fertilizer on soil acidity, soil phosphor (P) availability and P uptake in potatoes shoot; as well as yield and quality of tuber. The experimental design was a randomized block design with eight treatments and three replications. The treatment consisted of a combination of vermicompost doses (5 and 10 t ha^{-1}) with NPK fertilizer doses (0, 0.5 t ha^{-1} and 1.0 t ha^{-1}). The two control treatments were 1) without fertilizer and 2) the method of fertilizing local farmers included 10 t ha^{-1} chicken manure and 1 tha^{-1} NPK fertilizer. This experiment verified that vermicompost and NPK fertilizer increased plant height as well as soil P availability and acidity compared to those of control. Vermicompost has not yet substitute chicken manure to obtain the same tuber production although the percentage of marketable tuber was quite similar.

The effect of vermicompost on dry matter and specific gravity of potato tubers under ambient storage condition was studied by Ferdous *et al*. (2019). Vermicompost was used at four rates viz. 0, 2, 4 and 6 t ha^{-1} over the four varieties of potato viz. BARI TPS-1, BARI Alu-28 (Lady Rosetta), BARI Alu-25 (Asterix) and BARI Alu-29 (Courage). Results demonstrated that processing parameters such as dry matter percentage (%) and specific gravity increased with increasing vermicompost levels. Lady Rosetta and Asterix potato varieties can be safely stored at normal room temperature up to 60 days. There was no interaction between vermicompost rates and crop varieties. Hence, the potato growers of Bangladesh can use vermicompost at 6 t ha^{-1} for achieving better yield without affecting processing quality.

Above cited reviews revealed that potassium sources and vermicompost are the important factors for attaining optimum growth, yield attributes, yield and quality of potato. The literature revealed that the effects of potassium sources and vermicompost on potato have not been studied well and have no definite conclusion for the production of potato in respect of optimum growth, yield attributes, yield and quality in the agro climatic condition of Bangladesh.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to assess the effect of potassium sources and vermicompost level on yield and processing quality of potato. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatments and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Experimental site

3.1.1 Experimental period

The field experiment was conducted from the period of November, 2018 to February, 2019 and laboratory analysis was done in March, 2019.

3.1.2 Experimental location

The present study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location was $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. A map of the experimental location presented in Appendix I.

3.1.3 Climatic condition of the experimental site

The site of the experimental location is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the month of April to September and other periods are mostly without rainfall. The monthly average temperature, humidity, rainfall and sunshine hour during crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II. During the study period the maximum temperature (27.9^0C) was recorded in the month of February 2019, whereas the minimum temperature was (12.5^0C) in January 2019. The highest humidity (77%) was recorded in the month of November, 2019, while the highest rainfall (43 mm) in February 2019 and the highest sunshine hour (6.9 hour) in November, 2018.

3.1.4 Soil characteristics

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

3.2 Experimental details

3.2.1 Planting materials

The potato variety BARI Alu-25 (Asterix) was used as test crop for this experiment and tubers were collected from Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Potassium sources (3sources) as

- i K_1: KCl (260 kg KCl ha^{-1} = 130 kg K ha^{-1})
- ii. K_2: KNO_3(336.09 kg $KNO_3 ha^{-1}$ =130 kg Kha^{-1})
- iii. K_3: K_2SO_4 (309.2 kg K_2SO_4 ha^{-1} =130 kg K ha^{-1})

Factor B: Levels of vermicompost (4 levels) as

- i. Vm_0: 0 ton vermicompost ha^{-1}
- ii. Vm_1: 4 ton vermicompost ha^{-1}
- iii. Vm_2: 8 ton vermicompost ha^{-1}
- iv. Vm_3: 12 ton vermicompost ha^{-1}

There were total 12 (3×4) treatments combination such as K_1Vm_0, K_1Vm_1, K_1Vm_2, K_1Vm_3, K_2Vm_0, K_2Vm_1, K_2Vm_2, K_2Vm_3, K_3Vm_0, K_3Vm_1, K_3Vm_2 and K_3Vm_3.

3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in split-plot design with three replications. The total area was 340.75 m^2 with length 23.50 m and width 14.50 m. The three (3) sources of potassium were assigned in the main plot and four levels of vermicompost in the sub-plot. There were 36 unit plots with the size of 2.5 m × 1.0 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.3 Growing of crops

3.3.1 Preparation of the main field

The experimental plot was opened in the 2nd November 2018 with a power tiller and left exposed to the sun for a week. Subsequently cross ploughing was done five times followed by laddering to make the land suitable for planting of tubers with eliminated all weeds, stubbles and residues. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of insects such as cutworm and mole cricket.

3.3.2 Application of manure and fertilizer

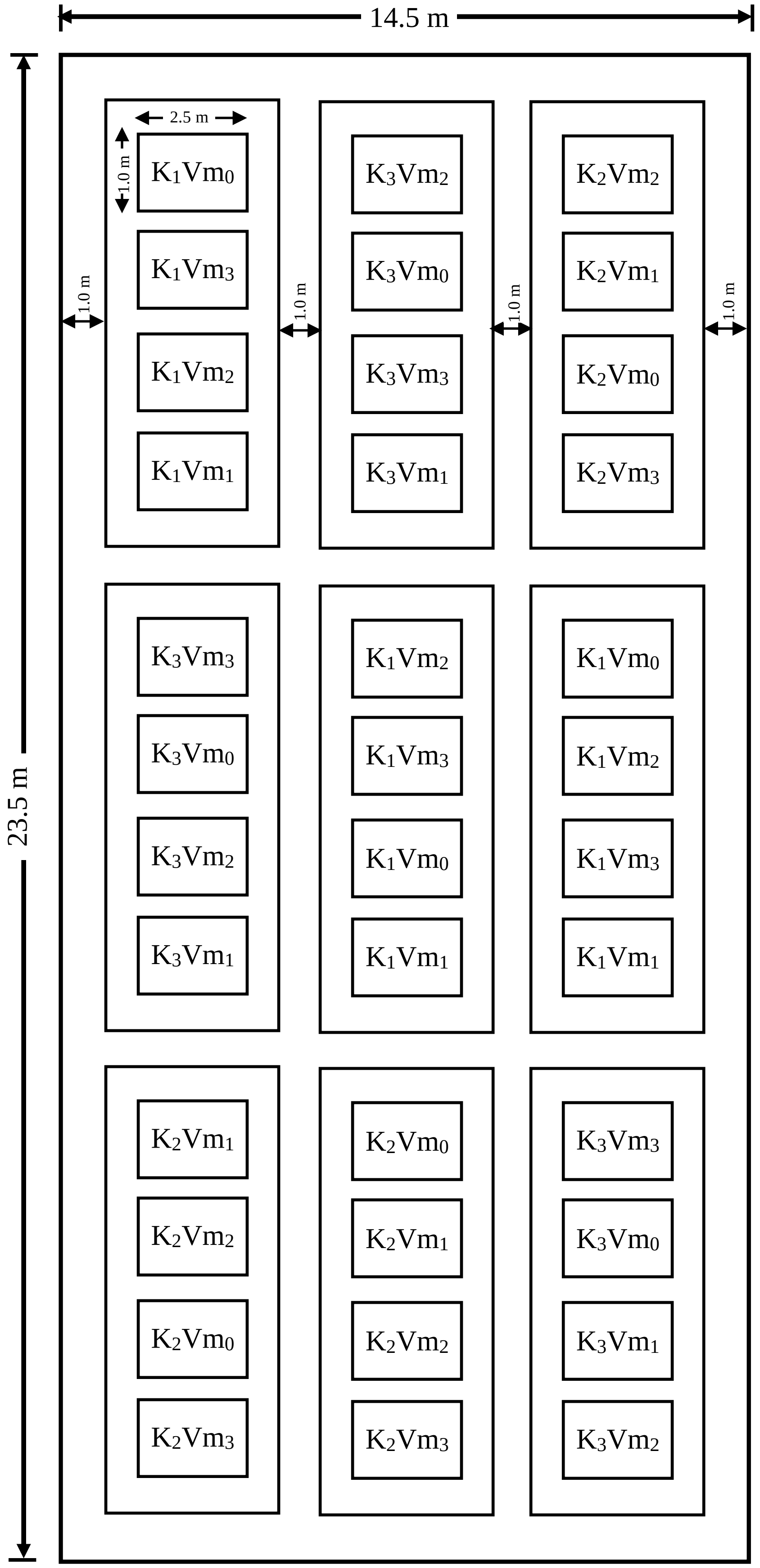
Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of potato and presented in Table 1.

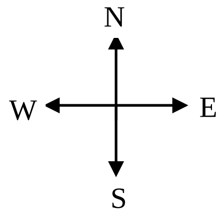
Table 1. Doses and methods of application of manure and fertilizers in the potato field

Manures and fertilizers	Dose ha^{-1}	Application (%)	
		Basal	50 DAP
Vermicompost	As per treatment	100	--
Urea	325 kg	50	50
TSP	200 kg	100	--
Zypsum	100 kg	100	--
Zinc Suphate	8 kg	100	--

Source: BARI, 2019

The entire amount of vermicompost and all fertilizers and half urea were applied during final land preparation. Rest amount of urea was applied during 2nd earthing up at 50 DAP. Potassium fertilizer were applied as per treatment and 260, 336.09 and 309.2 kg KCl, KNO_3 and K_2SO_4 respectively were applied for 130 kg K ha^{-1}.





Plot size: 2.5 m × 1.0 m

Plot spacing: 50 cm

Between replication: 1.0 m

Factor A: Potassium sources (3 sources) as

i. K_1: KCl

ii. K_2: KNO_3

iii. K_3: K_2SO_4

Factor B: Levels of vermicompost (4 levels) as

i. Vm_0: 0 ton vermicompost ha^{-1}

ii. Vm_1: 4 ton vermicompost ha^{-1}

iii. Vm_2: 8 ton vermicompost ha^{-1}

iv. Vm_3: 12 ton vermicompost ha^{-1}

Figure 1. Layout of the experimental plot

3.3.3 Planting of potato tubers

The seed tubers were planted at a depth of 5 cm in the experimental plots at 9th November, 2018 with maintaining a distance of 50 cm × 25 cm. The soil along the rows of seed tubers were ridged up immediately after planting.

3.3.4 Intercultural operations

When the seedlings started to emerge in the beds mulch materials were clean-up for easy growth and development of potato seedlings. The crop was always kept under careful observation. After emergence of potato seedlings, various intercultural operations were accomplished for better growth and development.

3.3.4.1 Weeding and mulching

Weeding was done at 30 and 50 DAP (days after planting) to remove the unwanted weeds and mulching was done to conserve soil moisture. Manual weeding was done as and when necessary to keep the plots free from weeds. The soil was mulched by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed. Mulching also helped to disturb the emergence of Bathua plants *(Chenopodium album)* and other weeds. These two operations were done carefully without hampering the luxurious crop health.

3.3.4.2Earthing-up

Two times earthing up was done at 30 and 50 DAP. The soil along the rows of seed tubers were ridged up immediately after planting. The earthing which was preceded by top dressing of the remaining half of urea and also it was treated as a final earthing-up.

3.3.4.3 Irrigation

Pre emergence irrigation was done seven days after planting of potato tubers as because moisture was not optimum for germination before emergence, light irrigation was done for even emergence of seed tuber. After emergence, four times irrigation was given throughout the growing period.

3.3.4.4 Pests and diseases control

Except cutworm, no other insects were found harmful for potato in growing season. To protect the soil borne insects Furadan 5G was applied @10kg ha^{-1} during the final land preparation. Dithane M-45 was applied @2g L^{-1} at 10 days interval as a preventive measure against late blight *(Phytophthora infestans)* of potato. This plant growing time was very cold so Dithane M 45 and Rovral 50 WP were applied alternatively at 3 days interval.

3.3.4.5 Haulm cutting

When the potato plants attained maturity the upper portion of the plants were cut down and tubers were kept under the soil for 07 days for skin hardening of potato. This haulm cutting was done at 2nd February, 2019.

3.4 Harvesting

The maturity of the tuber crops was determined by the appearance of the yellowish color of the leaves, falling of the stems on the ground and finally drying of leaves. Harvesting was done at 9th February 2019.The tubers from each plot were harvested manually.

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect and tagged with a sample card, which was done in plot wise for data recording. Data were collected in respect of the following parameters to estimate the plant growth; yield attributes, yields and quality of potato tubers as affected by different treatments that were used in this experiment. Data on plant height, number of leaves $plant^{-1}$, number of stems $plant^{-1}$ were collected at 30, 45, 60, 75 DAP and at harvest and recorded accordingly. All other yield contributing characters, yield parameters were recorded during harvest and after harvest as per suitability. Quality parameters of potato tubers was estimated in laboratory condition following the standard procedures of estimation as per different quality measures.

3.5.1 Growth, yield parameters and yield of potato

3.5.1.1 Days required for 1st emergence

Each plot of the experiment was kept under close observation from 10 DAP to count days required for 1st emergence of potato seedlings. Total number of days from the date of planting to the visible emergence was counted and recorded accordingly.

3.5.1.2 Days required for 80% emergence

Each plot of the experiment was kept under close observation to count days required for 80% emergence of potato seedlings. Total number of days from planting to 80% emergence was recorded.

3.5.1.3 Days required for planting to harvest

Each plot of the experiment was kept under close observation to count days required for harvest of potato plants. Total number of days from the date of planting to the harvesting was recorded.

3.5.1.4 Plant height

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 15 days' interval starting from 30 DAP upto 75 DAP and also at harvest to observe the growth rate of the potato plants.

3.5.1.5 Number of leaves plant^{-1}

The total number of leaves plant^{-1} was counted from each selected potato plants. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot at 15 days' interval starting from 30 DAP upto 75 DAP and also at harvest.

3.5.1.6 Number of stems plant^{-1}

The total number of stems plant^{-1} was counted from each selected plants. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot at 15 days' interval from 30 DAP to 75 DAP and also at harvest.

3.5.1.7 SPAD value of leaf

The SPAD value of leaves was measured at stolen initiation stage at 30 DAP by placing the Spadometer in middle point of any five leaves of each 5 previously tagged plants from each plot and then the percentage showed by the Spadometer was observed and recorded.

3.5.1.8 Number of tubers hill^{-1}

Total number of potato tubers hill^{-1} was recorded as the average of 5 plants selected at random from each unit plot at harvest. The total number of tubers were recorded by counting the entire potato hill^{-1}.

3.5.1.9 Weight of tubers hill^{-1}

Five earlier tagged hills from middle row was selected from each unit plot, and the yield of potato tubers obtained from the hills was collected and weighted and recorded according with expressed in g hill^{-1}.

3.5.1.10 Average weight of individual tuber

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

3.5.1.11 Yield of tubers hectare^{-1}

Tubers yield per hectare of potato was calculated by converting the weight of individual tubers yield from a plot and converted yield of tubers into hectare and was expressed in t ha^{-1}.

3.5.12 Seed Potato

The harvested potato tubers from 1 m^2 area of each unit plot were graded as seed potato (28-55 mm) and expressed in percentage.

3.5.1.13 Non-seed potato

The harvested potato tubers from 1 m^2 area of each unit plot were graded as non-seed potato (<28 mm and >55 mm) and expressed in percentage.

3.5.2 Quality of potato

3.5.2.1 Grading of potato tubers

The harvested potato tubers from 1 m^2 area of each unit plot were graded in to four size grades (<28 mm, 28-45 mm, 45-55 mm and >55 mm) and expressed in percentage.

3.5.2.2 Category of potato tubers for different uses

The harvested potato tubers from 1 m^2 area of each unit plot were classified for different purposive uses i.e. Canned (25-45 mm), Chips (45-75 mm) and French fry (>75 mm), potato and expressed in percentage.

3.5.2.3 Firmness score in potato tubers

Firmness score was estimated by using pressure gauge. For the estimation of firmness firstly the potato tubers was divided into two then created pressure using pressure gauge and recorded the reading from pressure gauge.

3.5.2.4 Estimation of Total Soluble Solids (TSS) in potato tubers

Total Soluble Solids (TSS) of harvested tubers was determined after harvest in a drop of potato juice by using Hand Sugar Refractometer "ERMA" Japan, Range: 0-32% according to (AOAC, 1990) and recorded as ^{o}brix from direct reading of the instrument.

3.5.2.5 Dry matter content of potato tubers

At first selected tubers were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at 70^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents in potato tubers were computed by simple calculation from the weight recorded using the following formula:

$$\text{Dry matter content (\%)} = \frac{\text{DRY WEIGHT}}{\text{FRESH WEIGHT}} \times 100$$

3.5.2.6 Estimation of specific gravity of potato tubers

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

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

Where,

Wa= Weight of tuber (g) in air and

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

3.5.2.7 Estimation of starch content of potato tubers

Starch content of potato tubers was determined after harvest by Somogyi-Nelson method (Nelson, 1944). Phosphate buffer solution was prepared through diluted 0.74g $NaH_2PO_4{\cdot}2H_2O$ and 0.09g $Na_2HPO_4.12H_2O$ into 100 ml Distilled water. Added 0.1 g Enzyme (Amyloglucosidase) and mixed well. Kept at -20^0C for the preservation. The residue remained after extraction for sugar was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stirred well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker during stirring into 3 test tubes. Boil the test tubes for 10 min at 100^0C. Add 1 ml Amyloglucosidase solution, mix well, and heat at 50-60^0C for 2 hours in hot water. After cooling, add 0.5 ml Copper solution, mix well, heat at 100^0C for 10 min., cool in tap water, add 0.5 ml Nelson solution, mix well, add 7 ml distilled water, mix well (Final volume = 9.5 ml), and measure the absorbance at 660 nm (Abs). Starch content was calculated using the glucose standard curve.

3.5.2.8 Estimation of vitamin C (ascorbic acid) content in potato tubers

Quantitative determination of ascorbic acid content of potato tubers from different treatment was estimated (AOAC, 1990) at Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. The applied method was as follows:

Reagents

i) Metaphosphoric acid solution (3% HPO_3): Prepared by dissolving pellets of HPO_3 in glass distilled water.

ii) Standard ascorbic acid solution: 100 mg of ascorbic acid was weighted, dissolved and made up to 100 ml with 3% HPO_3 and diluted to 0.1 mg/ml (10 ml HPO_3 of 1 mg/ml) immediately before use.

iii) Dye solution: Fifty milligram of 2, 6-Dichlorophenol indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. The mixture was cooled, diluted with distilled water up to 200 ml, stored in a refrigerator and standardizes every day before use.

Procedure

Five (5) grams of fresh potato tuber sample was crushed in a mortar and mixed well with 3% HPO_3 up to 100 ml in a volumetric flask. It was filtered with what man filter paper 40. Then 5 ml aliquot of HPO_3 extract of the sample was taken and titrated with dye solution.

3.5.2.9 Estimation of sugar content of potato tubers

For the analysis of sugar content like reducing sugar glucose potato flesh was extracted. For each extraction, 1 g fresh sample of chopped potato was taken from uniform tuber samples and smashed well in a motor. Sugar was extracted using 5 ml of 80% ethanol heat at 80^0C for 30 min using a dry block heat bath and the extracts was centrifuged at 5000 rpm for 10 min and decanted the supernatant. 8 mL 80% EtOH, was added and it was repeated 4 and 5 times in total. All the supernatants were mixed well and the final volume was made up to 25 mL using 80% EtOH. The residue is used for sugar analysis. Reducing sugar was estimated by the photometric adaptation of the Somogyi method (Nelson, 1944) with some modification. Copper solution and Nelson reagent and standard glucose solution (0.5 ml) were used. 3 mL sample solution was put into a small glass container. Then it was completely dried up on an electric heater, 3 mL distilled water was added and then mixed well.

Then 0.5 ml solution was taken from that, two times and was put in different test tubes. In one test tube, 0.5 ml Copper solution was added and was boiled (100^0C) for 10 min. After boiling, immediately the test tube was cooled in tap water. 0.5 mL Nelson reagent in the test tube was added, and mixed them well. After 20 min, 8 mL distilled water was added and mixed well (Total volume = 9.5 ml). After that the absorbance at 660 nm (Abs1) was measured and the reducing sugar content was calculated.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the effect and significance of the difference for potassium sources and levels of vermicompost on yield, yield contributing characters and quality of potato. The mean values of all the recorded parameters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment and treatment combinations of means under the experiment was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of source of potassium and different levels of vermicompost on yield and processing quality of potato. Analyses of variance (ANOVA) of the data on different yield attributes, yield and quality of potato are presented in Appendix IV-XI. The results have been presented with the help of table and graphs and possible interpretations given under the following headings and sub-headings:

4.1 Yield attributes and yield of potato

4.1.1 Days required for 1st emergence

Different sources of potassium showed statistically non-significant variations in terms of days required for 1st emergence of potato seedlings (Table 2). The maximum days required for 1st emergence (12.67) was recorded from K_1 (KCl) and the minimum days (12.08) was observed from K_2 (KNO_3) source of potassium. Neshev and Manolov (2016) also recorded similar findings in their earlier experiment.

Statistically non-significant differences was found in terms of days required for 1st emergence of potato seedlings for different levels of vermicompost (Table 2). The maximum days required for 1st emergence (12.80) was found from Vm_3 (12 ton vermicompost ha^{-1}), while the minimum days (11.89) was recorded from Vm_0 (0 ton vermicompost ha^{-1}). Mojtaba *et al.* (2013) reported that vermicompost application at the rate of 12 t ha^{-1} have no effect on days to seedling emergence.

Days required for 1st emergence of potato seedlings varied non-significantly due to the combined effect of different sources of potassium and levels of vermicompost (Table 3). The maximum days required for 1st emergence (13.00) was observed from K_1Vm_3 (KCl and 12 ton vermicompost ha^{-1}), whereas the minimum days (11.33) was found from K_2Vm_0 (KNO_3 and 0 ton vermicompost ha^{-1}) treatment combination.

Table 2. Effect of different sources of potassium and levels of vermicompost on days required for 1st and 80% emergence of seedlings and harvest of potato

Treatments	Days required for 1st emergence	Days required for 80% emergence	Days required for harvest
Source of potassium			
K_1	12.67	18.75	93.00
K_2	12.08	17.50	95.75
K_3	12.35	18.10	94.67
Sx	0.219	0.167	1.097
Level of significance	NS	NS	NS
CV(%)	5.66	12.15	4.07
Levels of vermicompost			
Vm_0	11.89	17.33	98.00 a
Vm_1	12.33	18.00	94.00 b
Vm_2	12.44	18.33	93.67 b
Vm_3	12.80	18.80	92.22 b
Sx	0.256	0.195	1.306
Level of significance	NS	NS	*
CV(%)	5.75	12.32	4.19

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; * = Significant at 5% level

Table 3. Combined effect of different sources of potassium and levels of vermicompost on days required for 1st and 80% emergence of seedlings and harvest of potato

Treatments	Days required for 1st emergence	Days required for 80% emergence	Days required for harvest
K_1Vm_0	12.33	18.33	95.67 ab
K_1Vm_1	12.67	18.67	91.67 b
K_1Vm_2	12.67	18.67	93.67ab
K_1Vm_3	13.00	19.33	91.00 b
K_2Vm_0	11.33	16.33	99.67 a
K_2Vm_1	12.33	17.66	95.33 ab
K_2Vm_2	12.00	17.67	94.33 ab
K_2Vm_3	12.67	18.34	93.67 ab
K_3Vm_0	12.00	17.33	98.67 ab
K_3Vm_1	12.00	17.67	95.00 ab
K_3Vm_2	12.67	18.67	93.00 ab
K_3Vm_3	12.73	18.73	92.00 ab
Sx	0.444	0.338	2.262
Level of significance	NS	NS	*
CV(%)	5.75	12.32	4.19

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; * = Significant at 5% level

4.1.2 Days required for 80% emergence

Days required for 80% emergence of potato seedlings varied non-significantly due to different sources of potassium (Table 2). The maximum days required for 80% emergence (18.75) was found from K_1, while the minimum days (17.50) was recorded from K_2 source of potassium.

Different levels of vermicompost varied non-significantly in terms of days required for 80% emergence (Table 2). The maximum days required for 80% emergence (18.80) was observed from Vm_3, whereas the minimum days (17.33) was obtained from Vm_0.

Statistically non-significant variation was recorded in terms of days required for 80% emergence due to the combined effect of different sources of potassium and levels of vermicompost (Table 3). The maximum days required for 80% emergence (19.33) was found from K_1Vm_3 and the minimum days (16.33) was recorded from K_2Vm_0 treatment combination.

4.1.3 Days required for harvest

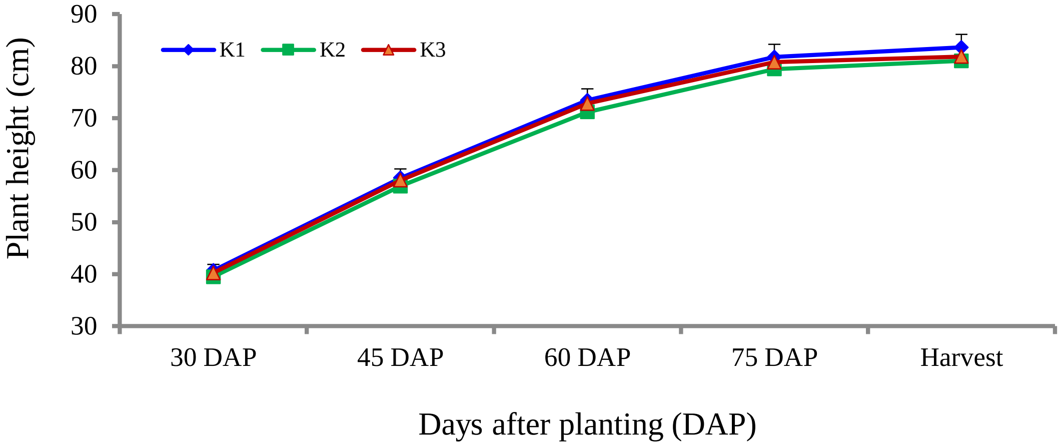
Different sources of potassium varied non-significantly in terms of days required for harvest of potato seedlings (Table 2). The maximum days required for harvest (95.75) was recorded from K_2, while the minimum days (93.00) was observed from K_1 source of potassium.

Statistically significant variation was recorded in terms of days required for harvest for different levels of vermicompost (Table 2). The maximum days required for harvest (98.00) was found from Vm_0 and the minimum days (92.22) from Vm_3 which was statistically similar (93.67 and 94.00 days) to Vm_2 and Vm_1.

Days required for harvest showed statistically significant differences due to the combined effect of different sources of potassium and levels of vermicompost (Table 3). The maximum days required for harvest (99.67) was observed from K_2Vm_0, while the minimum days (91.00) from K_1Vm_3 treatment combination.

4.1.4 Plant height

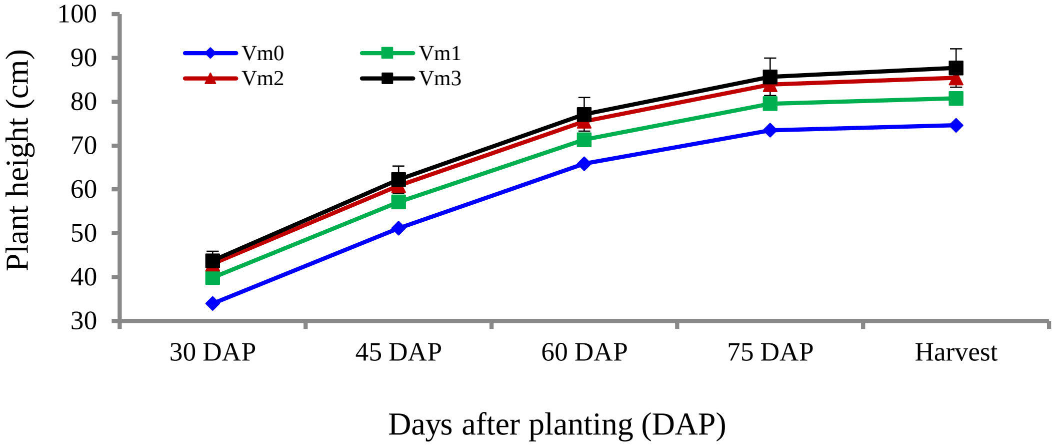
Different sources of potassium varied non-significantly in terms of plant height of potato at 30, 45, 60, 75 DAP (days after planting) and at harvest (Figure 2). At 30, 45, 60, 75 DAP and harvest, the tallest plant (40.68, 58.51, 73.43, 81.75 and 83.59 cm, respectively) was recorded from K_1, while the shortest plant (39.49, 56.91, 71.18, 79.45 and 81.83 cm, respectively) was found from K_2. Silva *et al*. (2018) recorded no significant effect of potassium source on yield components.



K_1: KCl; K_2: KNO_3 K_3: K_2SO_4;

Figure 2. Effect of sources of potassium on plant height of potato.

Plant height of potato at 30, 45, 60, 75 DAP and harvest varied significantly due to different levels of vermicompost (Figure 3). At 30, 45, 60, 75 DAP and harvest, the tallest plant (43.72, 62.23, 77.12, 85.66 and 87.72 cm, respectively) was recorded from Vm_3 which was statistically similar (42.98, 60.85, 75.56, 83.91 and 85.46 cm, respectively) to Vm_2 and followed (39.89, 57.11, 71.36, 79.55 and 80.78 cm, respectively) by Vm_1, whereas the shortest plant (33.94, 51.14, 65.86, 73.51 and 74.62 cm, respectively) was found from Vm_0. Shirzadi (2015) reported that with the increasing of vermicompost plant height also increased. But Mojtaba *et al.* (2013) also reported that vermicompost application at the rate of 12 t ha^{-1} promoted all traits of potato plants except plant height in compared to control treatment.



Vm_0: 0 ton vermicompost ha^{-1}; Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}; Vm_3: 12 ton vermicompost ha^{-1}

Figure 3. Effect of levels of vermicompost on plant height of potato.

Statistically significant variation was recorded in terms of plant height of potato at 30, 45, 60, 75 DAP and harvest due to the combined effect of different sources of potassium and levels of vermicompost (Table 4). At 30, 45, 60, 75 DAP and harvest, the tallest plant (45.84, 65.20, 81.06, 90.68 and 93.32 cm, respectively) was observed from K_1Vm_3, while the shortest plant (32.18, 48.48, 62.49, 68.77 and 70.02 cm, respectively) was recorded from K_2Vm_0 treatment combination.

4.1.5 Number of leaves plant^{-1}

Number of leaves plant^{-1} of potato at 30, 45, 60, 75 DAP and at harvest varied non-significantly due to different sources of potassium (Table 5). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (29.00, 49.40, 69.13, 74.68 and 75.73, respectively) was found from K_1, whereas the minimum number (27.80, 47.55, 67.60, 70.77 and 71.65, respectively) was observed from K_2. Generally number of leaves plant^{-1} is a genetical characters and it was mostly similar for specific number but prevalence environment manipulated the number of leaves plant$^{-1.}$Yakimenko and Naumova (2018) recorded potassium source on the basis of plant biological requirements that intended maximum numbers of leaves plant^{-1}.

Table 4. Combined effect of different sources of potassium and levels of vermicompost on plant height of potato at different days after planting (DAP) and harvest

Treatments	Plant height (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
K_1Vm_0	36.73 bc	51.15 e	66.34 ef	73.31 de	74.48 de
K_1Vm_1	36.81 bc	53.05 de	67.59 def	76.95 cd	78.31 cd
K_1Vm_2	43.34 a	64.66 ab	78.73 ab	86.07 ab	88.23 ab
K_1Vm_3	45.84 a	65.20 a	81.06 a	90.68 a	93.32 a
K_2Vm_0	32.18 d	48.48 e	62.49 f	68.77 e	70.02 e
K_2Vm_1	41.82 a	59.35 a-d	73.30 bcd	82.91 abc	84.16 bc
K_2Vm_2	41.05 ab	58.30 bcd	73.68 bc	83.57 abc	84.78 bc
K_2Vm_3	42.89 a	61.49 ab	75.24 b	82.55 bc	85.10 bc
K_3Vm_0	32.91 cd	53.78 cde	68.76 cde	78.44 bcd	79.37 cd
K_3Vm_1	41.04 ab	58.92 a-d	73.19 bcd	78.79 bcd	79.86 cd
K_3Vm_2	44.55 a	59.60 abc	74.27 bc	82.09 bc	83.36 bc
K_3Vm_3	42.41 a	60.01 abc	75.06 b	83.74 abc	84.72 bc
Sx	1.432	1.925	1.849	2.411	2.445
Level of significance	*	*	*	*	*
CV(%)	6.18	5.77	4.42	5.18	5.16

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

Table 5. Effect of different sources of potassium and levels of vermicompost on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Source of potassium					
K_1	29.00	49.40	69.13	74.68	75.73
K_2	27.80	47.55	67.60	70.77	71.65
K_3	28.60	48.85	68.10	72.53	73.42
Sx	0.321	0.797	0.669	2.542	1.434
Level of significance	NS	NS	NS	NS	NS
CV(%)	3.90	5.68	3.39	6.78	6.75
Levels of vermicompost					
Vm_0	24.67 c	43.62 c	64.18 c	67.16 c	68.13 c
Vm_1	27.87 b	47.60 b	67.47 b	72.47 b	73.49 b
Vm_2	30.42 a	51.00 a	70.18 a	74.96 a	75.91 a
Vm_3	30.91 a	52.18 a	71.29 a	76.07 a	76.87 a
Sx	0.521	0.603	0.941	1.467	1.352
Level of significance	**	**	**	**	**
CV(%)	5.49	3.72	4.13	6.06	5.51

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; ** = Significant at 1% level

Statistically significant differences was observed in terms of number of leaves plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest due to different levels of vermicompost (Table 5). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (30.91, 52.18, 71.29, 76.07 and 76.87, respectively) was observed from Vm_3 which was statistically similar (30.42, 51.00, 70.18, 74.96 and 75.91, respectively) to Vm_2 and followed (27.87, 47.60, 67.47, 72.47 and 73.49, respectively) by Vm_1, while the minimum number (24.67, 43.62, 64.18, 67.16 and 68.13, respectively) was recorded from Vm_0.Ferdous*et al.* (2019) reported from an earlier experiment that vermicompost at 6 t ha^{-1} for achieving highest number of leaves plant^{-1}.

Combined effect of different sources of potassium and levels of vermicompost varied significantly in terms of number of leaves plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest (Table 6). At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (31.93, 54.00, 72.53, 77.67 and 78.53, respectively) was found from K_1Vm_3 treatment combination and the minimum number (22.07, 41.73, 62.07, 65.13 and 66.20, respectively) was observed from K_2Vm_0 treatment combination.

4.1.6 Number of stems plant^{-1}

Statistically non-significant variation was recorded in terms of number of stems plant^{-1} of potato at 30, 45, 60, 75 DAP and at harvest due to different sources of potassium (Table 7). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (2.53, 4.48, 6.12, 6.67 and 6.72, respectively) was observed from K_1 and the minimum number (2.42, 4.37, 5.60, 6.43 and 6.52, respectively) was recorded from K_2. Salim *et al*. (2014) the higher rate of potassium obtained from silicate and potassium nitrate were more effective on enhancing the vegetative growth parameters especially number of stems plant^{-1} although it is a genetical characters.

Table 6. Combined effect of different sources of potassium and levels of vermicompost on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of leaves plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
K_1Vm_0	24.93 e	45.13 cd	64.87 de	70.13 abc	71.13 ab
K_1Vm_1	27.60 c-e	47.60 bc	68.60 a-d	75.33 a	76.67 a
K_1Vm_2	31.53 a	50.87 ab	70.53 abc	75.60 a	76.60 a
K_1Vm_3	31.93 a	54.00 a	72.53 a	77.67 a	78.53 a
K_2Vm_0	22.07 f	41.73 e	62.07 e	65.13 c	66.20 b
K_2Vm_1	27.80 cde	47.20 cd	66.00 b-e	69.67 abc	70.60 ab
K_2Vm_2	30.27 abc	50.60 ab	70.87 abc	74.07 ab	74.93 a
K_2Vm_3	31.07 ab	50.67 ab	71.47 ab	74.20 ab	74.87 a
K_3Vm_0	27.00 de	44.00 de	65.60 cde	66.20 bc	67.07 b
K_3Vm_1	28.20 bcd	48.00 bc	67.80 a-d	72.40 abc	73.20 ab
K_3Vm_2	29.47 a-d	51.53 a	69.13 a-d	75.20 a	76.20 a
K_3Vm_3	29.73 a-d	51.87 a	69.87 a-d	76.33 a	77.20 a
Sx	0.902	1.045	1.630	1.423	2.342
Level of significance	*	*	*	*	*
CV(%)	5.49	3.72	4.13	6.06	5.51

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

Table 7. Effect of different sources of potassium and levels of vermicompost on number of stems plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of stems plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
Source of potassium					
K_1	2.53	4.48	6.12	6.67	6.72
K_2	2.42	4.37	5.60	6.43	6.52
K_3	2.47	4.42	5.78	6.47	6.58
Sx	0.035	0.031	0.148	0.068	0.076
Level of significance	NS	NS	NS	NS	NS
CV(%)	4.79	2.37	8.78	3.63	3.97
Levels of vermicompost					
Vm_0	2.18 c	4.11 c	5.40 c	5.73 c	5.82 c
Vm_1	2.38 b	4.33 b	5.73 b	6.38 b	6.47 b
Vm_2	2.58 a	4.56 a	6.02 a	6.87 a	7.04 a
Vm_3	2.76 a	4.69 a	6.18 a	7.11 a	7.16 a
Sx	0.036	0.049	0.117	0.109	0.105
Level of significance	**	**	**	**	**
CV(%)	4.33	3.35	5.99	5.02	4.74

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; ** = Significant at 1% level

Number of stems plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest showed statistically significant differences due to different levels of vermicompost (Table 7). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (2.76, 4.69, 6.18, 7.11 and 7.16, respectively) was observed from Vm_3 which was statistically similar (2.58, 4.56, 6.02, 6.87 and 7.04, respectively) to Vm_2 and followed (2.38, 4.33, 5.73, 6.38 and 6.47, respectively) by Vm_1, whereas the minimum number (2.18, 4.11, 5.40, 5.73 and 5.82, respectively) was recorded from Vm_0. Mojtaba *et al.* (2013) also reported from an earlier experiment that vermicompost application at the rate of 12 t ha^{-1} promoted number of stems in compared to control treatment.

Combined effect of different sources of potassium and levels of vermicompost showed statistically significant differences in terms of number of stems plant^{-1} of potato at 30, 45, 60, 75 DAP and harvest (Table 8). At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (3.00, 4.93, 6.47, 7.47 and 7.53, respectively) was found from K_1Vm_3 treatment combination and the minimum number (2.13, 4.07, 5.13, 5.33 and 5.40, respectively) was observed from K_2Vm_0 treatment combination.

Table 8. Combined effect of different sources of potassium and levels of vermicompost on number of stems plant^{-1} of potato at different days after planting (DAP) and harvest

Treatments	Number of stems plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	Harvest
K_1Vm_0	2.20 ef	4.13 de	5.67 bcd	6.00 ef	6.07 de
K_1Vm_1	2.40 cd	4.20 cde	6.00 abc	6.07 def	6.20 de
K_1Vm_2	2.53 bc	4.67 b	6.33 ab	7.13 ab	7.27 ab
K_1Vm_3	3.00 a	4.93 a	6.47 a	7.47 a	7.53 a
K_2Vm_0	2.13 f	4.07 e	5.13 d	5.33 g	5.40 f
K_2Vm_1	2.33 de	4.40 bcd	5.73 bcd	6.60 b-e	6.60 cd
K_2Vm_2	2.60 b	4.47 bc	5.73 bcd	6.80 bc	7.07 abc
K_2Vm_3	2.60 b	4.53 b	5.80 a-d	7.00 abc	7.00 abc
K_3Vm_0	2.20 ef	4.13 de	5.40 cd	5.87 fg	6.00 e
K_3Vm_1	2.40 cd	4.40 bcd	5.47 cd	6.47 c-f	6.60 cd
K_3Vm_2	2.60 b	4.53 b	6.00 abc	6.67 bcd	6.80 bc
K_3Vm_3	2.67 b	4.60 b	6.27 ab	6.87 abc	6.93 bc
Sx	0.062	0.086	0.202	0.189	0.181
Level of significance	*	*	*	*	*
CV(%)	4.33	3.35	5.99	5.02	4.74

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

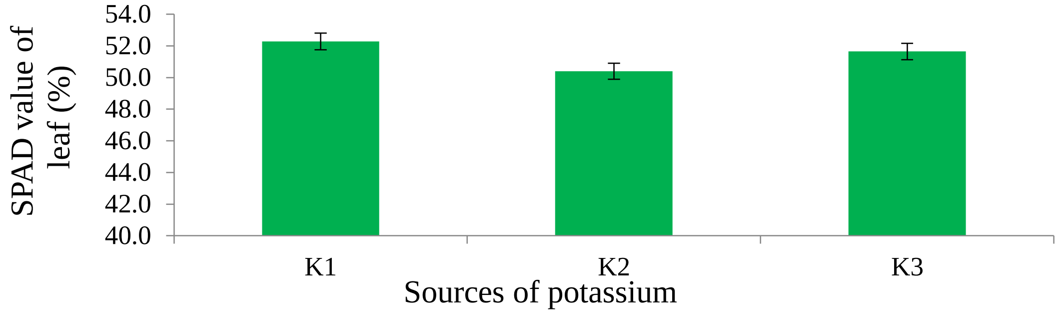
K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

4.1.7 SPAD value of leaf

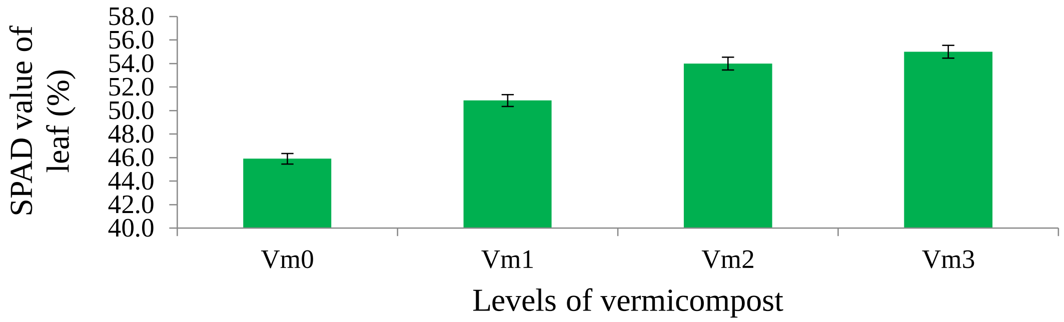
SPAD value of leaf at stolen initiation stage varied non-significantly due to different sources of potassium (Figure 4). The highest SPAD value of leaf (52.28%) was observed from K_1 and the lowest (50.40%) was found from K_2 source of potassium.



K_1: KCl; K_2: KNO_3 K_3: K_2SO_4;

Figure 4. Effect of sources of potassium on SPAD value of leaf of potato.

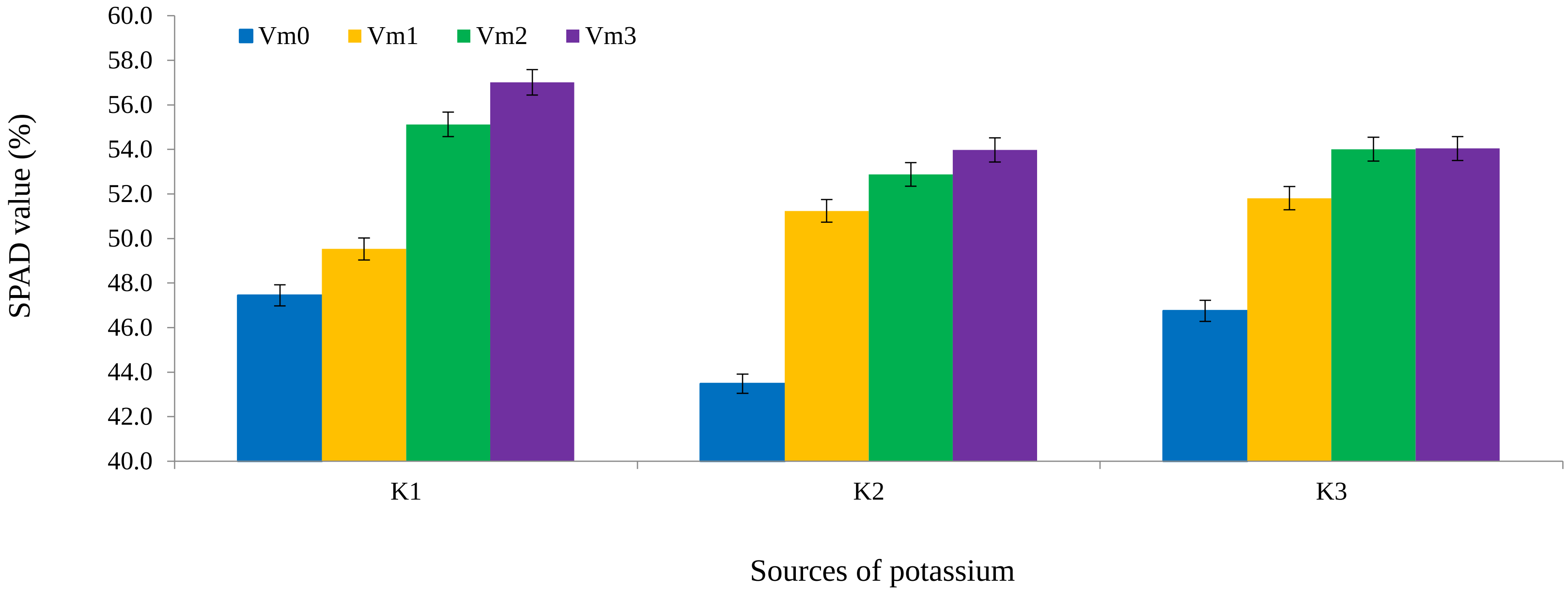
Different levels of vermicompost showed statistically significant differences in terms of SPAD value of leaf at stolen initiation stage (Figure 5). The highest SPAD value of leaf (55.01%) was recorded from Vm_3 which was statistically similar (54.00%) to Vm_2 and followed (50.86%) by Vm_1, while the lowest (45.90%) was observed from Vm_0.



Vm_0: 0 ton vermicompost ha^{-1}; Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}; Vm_3: 12 ton vermicompost ha^{-1}

Figure 5. Effect of levels of vermicompost on SPAD value of leaf of potato.

Combined effect of different sources of potassium and levels of vermicompost varied significantly in terms of SPAD value of leaf at stolen initiation stage (Figure 6). The highest SPAD value of leaf (57.01%) was found from K_1Vm_3 and the lowest (43.48%) from K_2Vm_0 treatment combination.



K_1: KCl; K_2: KNO_3 Vm_0: 0 ton vermicompost ha^{-1}; Vm_1: 4 ton vermicompost ha^{-1}

K_3: K_2SO_4; Vm_2: 8 ton vermicompost ha^{-1}; Vm_3: 12 ton vermicompost ha^{-1}

Figure 6. Combined effect of different sources of potassium and levels of vermicompost on SPAD value of leaf of potato.

4.1.8 Number of tubers hill^{-1}

Different sources of potassium varied significantly in terms of number of tubers hill^{-1} of potato (Table 9). The maximum number of tuber hill^{-1} (8.12) was observed from K_1 which was statistically similar (7.90) to K_3, while the minimum number (7.72) was recorded from K_2. Similar results also reported by Silva *et al*. (2018) from earlier experiment.

Number of tubers hill^{-1} of potato showed statistically significant differences due to different levels of vermicompost (Table 9). The maximum number of tubers hill^{-1} (8.33) was recorded from Vm_3 which was statistically similar (8.29) to Vm_2 and followed (7.82) by Vm_1, whereas the minimum number (7.20) was observed from Vm_0. Mojtaba *et al.* (2013) also reported that vermicompost application at the rate of 12 t ha^{-1} promoted number of tubers in compared to control treatment.

Statistically significant variation was recorded in terms of number of tubers hill^{-1} of potato due to the combined effect of different sources of potassium and levels of vermicompost (Table 10). The maximum number of tubers hill^{-1} (8.93) was found from K_1Vm_3, while the minimum number (6.87) was observed from K_2Vm_0 treatment combination.

4.1.9 Weight of tubers hill^{-1}

Weight of tubers hill^{-1} of potato varied significantly due to different sources of potassium (Table 9). The highest weight of tuber hill^{-1} (415.07 g) was observed from K_3 which was statistically similar (403.42 g) to K_1 and the lowest weight (357.21 g) was recorded from K_2. Salim *et al*. (2014) the higher rate of potassium silicate and potassium nitrate were more effective on yield components.

Different levels of vermicompost varied significantly in terms of weight of tubers hill^{-1} of potato (Table 9). The highest weight of tubers hill^{-1} (423.64 g) was found from Vm_3 which was statistically similar (416.58 g) to Vm_2 and followed (383.81 g) by Vm_1, while the lowest weight (343.57 g) was recorded from Vm_0. Mojtaba *et al.* (2013) also reported that vermicompost application at the rate of 12 t ha^{-1} promoted total tuber weight in compared to control treatment.

Table 9. Effect of different sources of potassium and levels of vermicompost on number and weight of tubers hill^{-1}, average weight of individual tubers, yield of potato, seed and non-seed potato

Treatments	Number of tubers hill^{-1}	Weight of tubers hill^{-1} (g)	Average weight of individual tuber (g)	Yield of potato (t ha^{-1})	Seed potato (%)	Non seed potato (%)
Source of potassium						
K_1	8.12 a	403.42 a	49.64 ab	27.33 ab	56.86	43.14
K_2	7.72 b	357.21 b	46.29 b	26.02 b	55.76	44.24
K_3	7.90 ab	415.07 a	52.55 a	27.86 a	56.23	43.77
Sx	0.073	6.576	1.039	0.353	0.520	0.520
Level of significance	*	**	*	*	NS	NS
CV(%)	3.20	5.81	7.27	4.52	3.20	4.12
Levels of vermicompost						
Vm_0	7.20 c	343.57 c	47.72 b	23.34 c	51.17 c	48.83 a
Vm_1	7.82 b	383.81 b	49.13 ab	26.44 b	55.33 b	44.67 b
Vm_2	8.29 a	416.58 a	50.21 a	28.89 a	58.77 a	41.23 c
Vm_3	8.33 a	423.64 a	50.91 a	29.61 a	59.87 a	40.13 c
Sx	0.103	5.999	0.655	0.459	0.759	0.759
Level of significance	**	**	**	**	**	**
CV(%)	3.92	4.59	3.97	5.09	4.05	5.21

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; ** = Significant at 1% level

Table 10. Combined effect of different sources of potassium and levels of vermicompost on number and weight of tubers hill^{-1}, average weight of individual tubers, yield of potato, seed and non-seed potato

Treatments	Number of tubers hill^{-1}	Weight of tubers hill^{-1} (g)	Average weight of individual tuber (g)	Yield of potato tubers(t ha^{-1})	Seed potato (%)	Non-seed potato (%)
K_1Vm_0	7.60cde	353.24 c	46.44 e	23.15fg	51.48 d	48.52 a
K_1Vm_1	7.40def	374.37 c	50.62bcd	24.80ef	53.22 cd	46.78 ab
K_1Vm_2	8.53 ab	435.84 ab	51.09abc	30.18 ab	60.26 ab	39.74 cd
K_1Vm_3	8.93 a	450.24 a	50.40bcd	29.43 abc	62.49 a	37.51 d
K_2Vm_0	6.87 f	308.24 d	44.86 e	22.09 g	50.23 d	49.77 a
K_2Vm_1	8.00 bc	360.89 c	45.15 e	26.34 de	56.54 bc	43.46 bc
K_2Vm_2	7.93bcd	374.96 c	47.30 de	27.44 cd	57.60 b	42.40 c
K_2Vm_3	8.07bc	384.75 c	47.84cde	28.21bcd	58.69 ab	41.31 cd
K_3Vm_0	7.13ef	369.23 c	51.84 ab	24.78ef	51.80 d	48.20 a
K_3Vm_1	8.07 bc	416.17 b	51.61 ab	28.19bcd	56.22 bc	43.78 bc
K_3Vm_2	8.40 ab	438.94 ab	52.25 ab	29.04abc	58.46 ab	41.54 cd
K_3Vm_3	8.00 bc	435.94 ab	54.49 a	31.17 a	58.44 ab	41.56 cd
Sx	0.179	10.390	1.134	0.795	1.315	1.315
Level of significance	**	*	*	*	*	*
CV(%)	3.92	4.59	3.97	5.09	4.05	5.21

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level ** = Significant at 1% level

Combined effect of different sources of potassium and levels of vermicompost varied significantly in terms of weight of tubers hill^{-1} of potato (Table 10). The highest weight of tubers hill^{-1} (450.24 g) was observed from K_1Vm_3, whereas the lowest weight (308.24 g) was recorded from K_2Vm_0 treatment combination.

4.1.10 Average weight of individual tuber

Statistically significant variation was recorded in terms of average weight of individual potato tuber due to different sources of potassium (Table 9). The highest average weight of individual tuber (52.55 g) was recorded from K_3 which was statistically similar (49.64 g) to K_1, whereas the lowest (46.29 g) was found from K_2.

Different levels of vermicompost showed statistically significant differences in terms of average weight of individual weight of potato tuber (Table 9). The highest average weight of individual tuber (50.91 g) was recorded from Vm_3 which was statistically similar (50.21 g and 49.13 g, respectively) to Vm_2 and Vm_1, while the lowest (47.72 g) was found from Vm_0.

Average weight of individual potato tuber showed statistically significant differences due to the combined effect of different sources of potassium and levels of vermicompost (Table 10). The highest average weight of individual potato tubers (54.49 g) was found from K_3Vm_3, whereas the lowest (44.86 g) was observed from K_2Vm_0 treatment combination.

4.1.11 Yield of potato tubers hectare^{-1}

Statistically significant variation was recorded in terms of yield of potato tubers hectare^{-1} due to different sources of potassium (Table 9). The highest yield of potato tubers (27.86 t ha^{-1}) was recorded from K_3 which was statistically similar (27.33 t ha^{-1}) to K_1, while the lowest yield (26.02 t ha^{-1}) was found from K_2. Silva *et al*. (2018) recorded no significant effect of potassium source on yield of potato.

Different levels of vermicompost showed statistically significant differences in terms of yield of potato tubers hectare^{-1} (Table 9). The highest yield of potato tubers (29.61 t ha^{-1}) was recorded from Vm_3 which was statistically similar (28.89 t ha^{-1}) to Vm_2 and followed (26.44 t ha^{-1}) by Vm_1, while the lowest yield (23.34 t ha^{-1}) was found from Vm_0. Ferdous *et al*. (2019) reported that vermicompost at 6 t ha^{-1} for achieving better yield with ensuring optimum yield attributes.

Yield of potato tubers hectare^{-1} showed statistically significant differences due to the combined effect of different sources of potassium and levels of vermicompost (Table 10). The highest yield of potato tubers (31.17 t ha^{-1}) was found from K_3Vm_3, whereas the lowest yield (22.09 t ha^{-1}) was observed from K_2Vm_0 treatment combination.

4.1.12 Seed potato tubers

Different sources of potassium varied non-significantly in terms of seed potato tubers (Table 9). The highest seed potato tubers (56.86%) was found from K_1, while the lowest (55.76%) was observed from K_2.

Seed potato tubersshowed statistically significant differences due to different levels of vermicompost (Table 9). The highest seed potato tubers (59.87%) was observed from Vm_3 which was statistically similar (58.77%) to Vm_2 and followed (55.33%) by Vm_1, whereas the lowest (51.17%) was recorded from Vm_0.

Statistically significant variation was recorded in terms of seed potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 10). The highest seed potato tubers (62.49%) was found from K_1Vm_3, while the lowest (50.23%) was observed from K_2Vm_0 treatment combination.

4.1.13 Non-seed potato tubers

Non-seed potato tubers varied non-significantly due to different sources of potassium (Table 9). The highest non-seed potato tubers (44.24%) was observed from K_2 and the lowest (43.14%) was recorded from K_1.

Different levels of vermicompost showed statistically significant differences in terms of non-seed potato tubers (Table 9). The highest non-seed potato tubers (48.83%) was found from Vm_0 which was followed (44.67%) by Vm_1, whereas the lowest (40.13%) was recorded from Vm_3 which was statistically similar (40.13%) to Vm_3.

Combined effect of different sources of potassium and levels of vermicompost showed statistically significant differences in terms of non-seed potato tubers (Table 10). The highest non-seed potato tubers (49.77%) was found from K_2Vm_0 and the lowest (37.51%) was observed from K_1Vm_3 treatment combination.

4.2 Quality of potato tubers

4.2.1 Grading of potato tubers

Different sources of potassium varied non-significantly in terms of grading (>55 mm, 45-55 mm, 28-45 mm, and <28 mm) of potato tubers (Table 11). In case of >55 mm, 45-55 mm and 28-45 mm grading, the highest (8.57%, 26.44% and 41.98%, respectively) was observed from K_1, while the lowest (8.36%, 25.28% and 40.39%, respectively) was recorded from K_2. In consideration of <28 mm grading, the highest (25.97%) was found from K_2, while the lowest (23.00%) was attained from K_1.

Grading (>55 mm, 45-55 mm, 28-45 mm, and <28 mm) of potato tubers showed statistically significant differences due to different levels of vermicompost (Table 11). In consideration of >55 mm, 45-55 mm and 28-45 mm grading, the highest (8.85%, 27.31% and 43.26%) was found from Vm_3 which was statistically similar (8.72%, 26.89% and 42.65%) by Vm_2 and followed (8.37%, 25.74% and 40.82%) by Vm_1, whereas the lowest (7.90%, 23.56% and 37.80%) was recorded from Vm_0. In consideration of <28 mm grading, the highest (30.75%) was found from Vm_0 which was followed (25.07%) by Vm_1, while the lowest (20.57%) was observed from Vm_3 which was statistically similar (21.74%) to Vm_2.

Table 11. Effect of different sources of potassium and levels of vermicompost on different grading of harvested potato

Treatments	Grading of potato tubers (%)			
	>55 mm	45-55 mm	28-45 mm	<28 mm
Source of potassium				
K_1	8.57	26.44	41.98	23.00
K_2	8.36	25.28	40.39	25.97
K_3	8.45	25.90	41.03	24.62
Sx	0.130	0.637	0.453	1.072
Level of significance	NS	NS	NS	NS
CV(%)	5.32	8.53	3.81	15.13
Levels of vermicompost				
Vm_0	7.90 c	23.56 c	37.80 c	30.75 a
Vm_1	8.37 b	25.74 b	40.82 b	25.07 b
Vm_2	8.72 a	26.89 ab	42.65 a	21.74 c
Vm_3	8.85 a	27.31 a	43.26 a	20.57 c
Sx	0.114	0.474	0.485	0.821
Level of significance	**	**	**	**
CV(%)	4.05	5.50	3.54	10.04

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; ** = Significant at 1% level

Statistically significant variation was recorded in terms of grading (>55 mm, 45-55 mm, 28-45 mm, and <28 mm) of potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 12). For >55 mm, 45-55 mm and 28-45 mm grading, the highest (9.15%, 28.09% and 44.52%) was found from K_1Vm_3, while the lowest (7.56%, 22.75% and 36.93%) was observed from K_2Vm_0 treatment combination. In case of <28 mm grading, the highest (32.76%) was found from K_2Vm_0, while the lowest (18.23%) was observed from K_1Vm_3 treatment combination.

4.2.2 Category of potato tubers for different uses

Category (Canned, 25-35 mm; Chips- >45 mm; and French fry- >75 mm) of potato tubers varied non-significantly due to different sources of potassium (Table 13). For Canned, Chips and French fry potato, the highest (35.56%, 31.69% and 5.25%, respectively) was observed from K_1, whereas the lowest (34.48%, 30.43% and 5.14%, respectively) was recorded from K_2.

Different levels of vermicompost showed statistically significant differences in terms of category (Canned, 25-35 mm; Chips- >45 mm; and French fry- >75 mm) of potato tubers (Table 13). In consideration of Canned, Chips and French fry potato, the highest (37.82%, 33.13% and 5.82%) was found from Vm_3 which was statistically similar (37.00%, 32.609% and 5.70%) by Vm_2 and followed (34.38%, 31.07% and 5.34%) by Vm_1, while the lowest (30.84%, 27.45% and 3.90%) was recorded from Vm_0.

Combined effect of different sources of potassium and levels of vermicompost showed statistically significant differences in terms of category (Canned, 25-35 mm; Chips- >45 mm; and French fry- >75 mm) of potato tubers (Table 14). For Canned, Chips and French fry potato, the highest (39.67%, 34.17% and 6.08%) was found from K_1Vm_3, whereas the lowest (29.73%, 26.59% and 3.83%) was recorded from K_2Vm_0 treatment combination.

Table 12. Combined effect of different sources of potassium and levels of vermicompost on different grading of harvested potato

Treatments	Grading of potato tubers (%)			
	>55 mm	45-55 mm	28-45 mm	<28 mm
K_1Vm_0	8.03 de	24.33 cde	38.91 de	28.74 ab
K_1Vm_1	8.23 bcd	26.08 a-d	41.11 bcd	24.59 bcd
K_1Vm_2	8.88 ab	27.27 ab	43.40 ab	20.45 de
K_1Vm_3	9.15 a	28.09 a	44.52 a	18.23 e
K_2Vm_0	7.56 e	22.75 e	36.93 e	32.76 a
K_2Vm_1	8.50 a-d	25.25 b-e	40.21 cd	26.04 bc
K_2Vm_2	8.65 a-d	26.46 abc	42.04 abc	22.85 cde
K_2Vm_3	8.73 abc	26.68 abc	42.38 abc	22.22 cde
K_3Vm_0	8.12 cde	23.59 de	37.55 e	30.73 a
K_3Vm_1	8.39 bcd	25.88 a-d	41.15 bcd	24.58 bcd
K_3Vm_2	8.64 a-d	26.95 abc	42.51 abc	21.91 cde
K_3Vm_3	8.67 a-d	27.17 ab	42.90 abc	21.27 de
Sx	0.198	0.822	0.841	1.422
Level of significance	*	*	*	*
CV(%)	4.05	5.50	3.54	10.04

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

Table 13. Effect of different sources of potassium and levels of vermicompost on harvested potato for canned, chips, french fry, firmness score and content of total soluble solid (TSS)

Treatments	Category of potato tubers (%) for different uses			Firmness score (N)	Total soluble solids – TSS (^{0}Brix)
	Canned (25-45 mm)	Chips (45-75mm)	French fry (>75 mm)		
Source of potassium					
K_1	35.56	31.69	5.25	39.76	3.97
K_2	34.48	30.43	5.14	38.92	3.89
K_3	35.00	31.08	5.18	39.29	3.93
Sx	0.356	0.644	0.054	0.404	0.027
Level of significance	NS	NS	NS	NS	NS
CV(%)	3.52	7.18	3.61	3.56	2.41
Levels of vermicompost					
Vm_0	30.84 c	27.45 c	3.90 c	35.26 c	4.19 a
Vm_1	34.38 b	31.07 b	5.34 b	38.61 b	4.12 a
Vm_2	37.00 a	32.60 a	5.70 a	41.30 a	3.88 b
Vm_3	37.82 a	33.13 a	5.82 a	42.12 a	3.53 c
Sx	0.456	0.494	0.061	0.616	0.042
Level of significance	**	**	**	**	**
CV(%)	3.91	4.77	3.52	4.70	3.19

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; ** = Significant at 1% level

Table 14. Combined effect of different sources of potassium and levels of vermicompost on harvested potato for canned, chips, french fry, firmness score and content of total soluble solid (TSS)

Treatments	Category of potato tubers (%) for different uses			Firmness score (N)	Total soluble solids –TSS (^{0}Brix)
	Canned (25-45 mm)	Chips (45-75 mm)	French fry (>75 mm)		
K_1Vm_0	31.39 ef	28.25 cd	3.93 e	35.58 d	4.38 a
K_1Vm_1	32.97 de	31.19 b	5.11 d	36.97 cd	4.22 ab
K_1Vm_2	38.19 ab	33.14 ab	5.87 ab	42.49 ab	3.73 d
K_1Vm_3	39.67 a	34.17 a	6.08 a	44.01 a	3.58 de
K_2Vm_0	29.73 f	26.59 d	3.83 e	34.65 d	4.11 bc
K_2Vm_1	35.04 cd	30.70 bc	5.45 c	39.39 bc	4.04 bc
K_2Vm_2	36.14 bc	32.03 ab	5.57 bc	40.31 bc	3.96 c
K_2Vm_3	37.00 bc	32.39 ab	5.71 bc	41.35 ab	3.45 e
K_3Vm_0	31.40 ef	27.52 d	3.93 e	35.56 d	4.09 bc
K_3Vm_1	35.14 cd	31.33 ab	5.45 c	39.47 bc	4.11 bc
K_3Vm_2	36.67 bc	32.62 ab	5.68 bc	41.11 ab	3.95 c
K_3Vm_3	36.79 bc	32.83 ab	5.66 bc	41.00 ab	3.56 de
Sx	0.790	0.856	0.106	1.066	0.072
Level of significance	*	*	*	*	*
CV(%)	3.91	4.77	3.52	4.70	3.19

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

4.2.3 Firmness score of potato tubers

Different sources of potassium varied non-significantly in terms of firmness score of potato tubers (Table 13). The highest firmness score of potato tubers (39.76 N) was found from K_1, while the lowest score (38.92 N) was recorded from K_2.

Firmness score of potato tubers showed statistically significant differences due to different levels of vermicompost (Table 13). The highest firmness score of potato tubers (42.12 N) was observed from Vm_3 which was statistically similar (41.30 N) to Vm_2 and followed (38.61 N) by Vm_1, whereas the lowest score (35.26 N) was recorded from Vm_0.

Statistically significant variation was recorded in terms of firmness score of potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 14). The highest firmness score of potato tubers (44.01 N) was found from K_1Vm_3, while the lowest score (34.65 N) was observed from K_2Vm_0 treatment combination.

4.2.4 Total soluble solids –TSS in potato tubers

Statistically non-significant variation was recorded in terms of TSS of potato tubers due to different sources of potassium (Table 13). The highest TSS in potato tubers (3.97^0Brix) was recorded from K_1, whereas the lowest (3.89^0 Brix) was found K_2.

TSS of potato tubers showed statistically significant differences due to different levels of vermicompost (Table 13). The highest TSS in potato tubers (4.19^0 Brix) was recorded from Vm_0 which was statistically similar (4.12^0 Brix) to Vm_1 and followed (3.88^0 Brix) by Vm_2 and the lowest (3.53^0 Brix) was observed from Vm_3.

Statistically significant differences was observed in terms of TSS in potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 14). The highest TSS in potato tubers (4.38^0 Brix) was observed from K_1Vm_0, whereas the lowest (3.45^0Brix) from K_2Vm_3 treatment combination.

4.2.5 Dry matter content in potato tubers

Statistically significant variation was recorded in terms of dry matter content in potato tubers due to different sources of potassium (Table 15). The highest dry matter content in potato tubers (19.83%) was recorded from K_3 which was statistically similar (19.20%) to K_1, while the lowest (18.74%) was found from K_2. Yakimenko and Naumova (2018) reported that the application of K fertilizer in the form of sulphate as compared to chloride increased dry matter content.

Different levels of vermicompost varied significantly in terms of dry matter content in potato tubers (Table 15). The highest dry matter content in potato tubers (20.24%) was recorded from Vm_3 which was statistically similar (20.14%) to Vm_2 and followed (19.08%) by Vm_1, whereas the lowest (17.57%) was found from Vm_0. Ferdous *et al.* (2019) reported that dry matter (%) increased with increasing vermicompost levels.

Dry matter content in potato tubers showed statistically significant differences due to the combined effect of different sources of potassium and levels of vermicompost (Table 16). The highest dry matter content in potato tubers (21.12%) was observed from K_3Vm_3 and the lowest (17.17%) was recorded from K_2Vm_0 treatment combination.

4.2.6 Specific gravity of potato tubers

Different sources of potassium varied significantly in terms of specific gravity of potato tubers (Table 15). The highest specific gravity of potato tubers (1.090) was found from K_3which was followed (1.072) by $K_1$and the lowest (1.043) was observed from K_2. Silva *et al.* (2018) recorded no significant effect of potassium source on specific gravity.

Specific gravity of potato tubers showed statistically significant differences due to different levels of vermicompost (Table 15). The highest specific gravity of potato tubers (1.083) was found from Vm_3 which was statistically similar (1.077 and 1.067, respectively) to Vm_2 and by Vm_1, while the lowest (1.046) was observed from Vm_0. Ferdous *et al.* (2019) reported that specific gravity increased with increasing vermicompost levels.

Table 15. Effect of different sources of potassium and levels of vermicompost on dry matter content, specific gravity, starch, vitamin C and sugar content in potato tubers

Treatments	Dry matter content in tubers (%)	Specific gravity	Starch (%)	Vitamin C (mg 100 g^{-1})	Sugar (%)
Source of potassium					
K_1	19.20 ab	1.072 b	14.04 b	22.45	1.191 b
K_2	18.74 b	1.043 c	13.63 b	22.10	1.220 ab
K_3	19.83 a	1.090 a	14.81 a	22.20	1.245 a
Sx	0.176	0.006	0.175	0.189	0.009
Level of significance	*	**	*	NS	*
CV(%)	3.17	1.94	4.28	2.94	2.59
Levels of vermicompost					
Vm_0	17.57 c	1.046 b	11.96 c	20.13 c	1.323 a
Vm_1	19.08 b	1.067 ab	13.88 b	21.82 b	1.233 b
Vm_2	20.14 a	1.077 ab	15.19 a	23.31 a	1.199 b
Vm_3	20.24 a	1.083 a	15.61 a	23.75 a	1.119 c
Sx	0.267	0.009	0.172	0.256	0.013
Level of significance	**	*	**	**	**
CV(%)	4.16	4.40	5.64	3.46	3.27

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

K_1: KCl
K_2: KNO_3
K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}
Vm_1: 4 ton vermicompost ha^{-1}
Vm_2: 8 ton vermicompost ha^{-1}
Vm_3: 12 ton vermicompost ha^{-1}

NS = Non-significant; * = Significant at 5% level ** = Significant at 1% level

Table 16. Combined effect of different sources of potassium and levels of vermicompost on dry matter content, specific gravity, starch, vitamin C and sugar content in potato tubers

Treatments	Dry matter content in tubers (%)	Specific Gravity	Starch (%)	Vitamin C (mg 100 g^{-1})	Sugar (%)
K_1Vm_0	17.22 e	1.053 ab	11.83 gh	20.16 d	1.288 ab
K_1Vm_1	19.12 bcd	1.070 ab	13.97 de	20.88 d	1.233 bc
K_1Vm_2	19.92 abc	1.073 ab	14.40 cd	23.95 ab	1.162 cde
K_1Vm_3	20.52 ab	1.090 a	15.97 ab	24.81 a	1.081 e
K_2Vm_0	17.17 e	1.013 b	11.50 h	20.06 d	1.327 a
K_2Vm_1	18.97 cd	1.027 b	13.27 ef	22.28 c	1.190 cd
K_2Vm_2	19.74 a-d	1.067 ab	15.23 bc	22.74 bc	1.211 bc
K_2Vm_3	19.07 bcd	1.063 ab	14.53 cd	23.33 bc	1.153 cde
K_3Vm_0	18.32 de	1.070 ab	12.54 fg	20.16 d	1.355 a
K_3Vm_1	19.15 bcd	1.097 a	14.41 cd	22.30 c	1.277 ab
K_3Vm_2	20.75 a	1.090 a	15.94 ab	23.23 bc	1.224 bc
K_3Vm_3	21.12 a	1.103 a	16.34 a	23.12 bc	1.122 de
Sx	0.463	0.015	0.298	0.444	0.023
Level of significance	*	*	*	*	*
CV(%)	4.16	4.40	5.64	3.46	3.27

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

K_1: KCl

K_2: KNO_3

K_3: K_2SO_4

Vm_0: 0 ton vermicompost ha^{-1}

Vm_1: 4 ton vermicompost ha^{-1}

Vm_2: 8 ton vermicompost ha^{-1}

Vm_3: 12 ton vermicompost ha^{-1}

* = Significant at 5% level

Statistically significant variation was recorded in terms of specific gravity of potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 16). The highest specific gravity of potato tubers (1.103) was recorded from K_3Vm_3, whereas the lowest (1.013) was found from K_2Vm_0 treatment combination.

4.2.7 Starch content in potato tubers

Starch content in potato tubers varied significantly due to the different sources of potassium (Table 15). The highest starch content in potato tubers (14.81%) was observed from K_3, whereas the lowest starch content (13.63%) from K_2 which was statistically similar (14.04%) to K_1.

Statistically significant variation was observed in terms of starch content in potato tubersdue to different levels of vermicompost (Table 15). The highest starch content in potato tubers (15.61%) was recorded from Vm_3 which was statistically similar (15.19%) to Vm_2 and followed (13.88%) by Vm_1, while the lowest (11.96%) was obtained from Vm_0.

Combined effect of different sources of potassium and levels of vermicompost showed statistically significant differences in terms of starch content in potato tubers (Table 16). The highest starch content in potato tubers (16.34%) was recorded from K_3Vm_3, whereas the lowest (11.50%) was observed from K_2Vm_0 treatment combination.

4.2.8 Vitamin C content in potato tubers

Different sources of potassium varied non-significantly in terms of vitamin C content in potato tubers (Table 15). The highest vitamin C content in potato tubers (22.45 mg 100 g^{-1}) was observed from K_1, while the lowest (22.10 mg 100 g^{-1}) was recorded from K_2. Yakimenko and Naumova (2018) reported that the application of K fertilizer in the form of sulphate as compared to chloride increased ascorbic acid content from 13.2 to 14.6 mg 100 g^{-1} fresh mass.

Vitamin C content in potato tubers showed statistically significant differences due to different levels of vermicompost (Table 15). The highest vitamin C content in potato tubers (23.75 mg 100 g^{-1}) was observed from Vm_3 which was statistically similar (23.31 mg 100 g^{-1}) to Vm_2 and followed (21.82 mg 100 g^{-1}) by Vm_1, whereas the lowest (20.13 mg 100 g^{-1}) was recorded from Vm_0.

Statistically significant variation was recorded in terms of vitamin C content in potato tubers due to the combined effect of different sources of potassium and levels of vermicompost (Table 16). The highest vitamin C content in potato tubers (24.81 mg 100 g^{-1}) was found from K_1Vm_3, while the lowest (20.06 mg 100 g^{-1}) was observed from K_2Vm_0 treatment combination.

4.2.9 Sugar content in potato tubers

Sugar content in potato tubers varied significantly due to different sources of potassium (Table 15). The highest sugar content in potato tubers (1.245%) was found from K_3 which was statistically similar (1.220%) to K_2, whereas the lowest (1.191%) was observed from K_1. Manolov *et al*. (2005) reported that sugars were influenced by potassium source.

Statistically significant variation was obtained in terms of sugar content in potato tubers due to different levels of vermicompost (Table 15). The highest sugar content in potato tubers (1.323%) was recorded from Vm_0 which was followed (1.233% and 1.199%, respectively) by Vm_1 and Vm_2 and they were statistically similar, while the lowest (1.119%) was observed from Vm_3.

Combined effect of different sources of potassium and levels of vermicompost showed statistically significant differences in terms of sugar content in potato tubers (Table 16). The highest sugar content in potato tubers (1.355%) was found from K_3Vm_0, whereas the lowest (1.081%) was recorded from K_1Vm_3 treatment combination.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from the period of November, 2018 to February, 2019 to assess the effect of potassium sources and vermicompost level on yield and processing quality of potato. The potato variety BARI Alu-25 (Asterix) were used as test crop for this experiment. The experiment consisted of two factors: Factor A: Potassium sources (3 sources) as- K_1: KCl, K_2: KNO_3, K_3: K_2SO_4; Factor B: Levels of vermicompost (4 levels) as- Vm_0: 0 ton vermicompost ha^{-1}, Vm_1: 4 ton vermicompost ha^{-1}, Vm_2: 8 ton vermicompost ha^{-1} and Vm_3: 12 ton vermicompost ha^{-1}. The two factorial experiment was laid out in split-plot design with three replications. Data were recorded on different yield attributes, yield and quality of potato and non-significant variations was observed for different sources of potassium and significant differences was recorded for different levels of vermicompost and the combined effect of different sources of potassium and levels of vermicompost.

In case of different sources of potassium, the maximum days required for 1st emergence (12.67) was recorded from K_1 and the minimum days (12.08) from K_2source of potassium. The maximum days required for 80% emergence (18.75) was found from K_1, while the minimum days (17.50) from K_2. The maximum days required for harvest (95.75) was recorded from K_2, while the minimum days (93.00) from K_1.At 30, 45, 60, 75 DAP and harvest, the tallest plant (40.68, 58.51, 73.43, 81.75 and 83.59 cm, respectively) was recorded from K_1, while the shortest plant (39.49, 56.91, 71.18, 79.45 and 81.83 cm, respectively) from K_2.At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves $plant^{-1}$ (29.00, 49.40, 69.13, 74.68 and 75.73, respectively) was found from K_1, whereas the minimum number (27.80, 47.55, 67.60, 70.77 and 71.65, respectively) from K_2.At 30, 45, 60, 75 DAP and harvest, the maximum number of stems $plant^{-1}$(2.53, 4.48, 6.12, 6.67 and 6.72, respectively) was observed from K_1 and the minimum number (2.42, 4.37, 5.60, 6.43 and 6.52, respectively) from K_2. The highest SPAD value of leaf (52.28%) was observed from K_1 and the lowest (50.40%) from K_2. The maximum number of tuber hill^{-1} (8.12) was observed from K_1, while the minimum number (7.72) from K_2. The highest weight of tuber hill^{-1} (415.07 g) was observed from K_3 and the lowest weight (357.21 g) from K_2. The highest average weight of individual tuber (52.55 g) was recorded from K_3, whereas the lowest (46.29 g) from K_2. The highest yield of potato tubers (27.86 t ha^{-1}) was recorded from K_3, while the lowest yield (26.02 t ha^{-1}) from K_2.The highest seed potato tubers (56.86%) was found from K_1, while the lowest (55.76%) from K_2. The highest non-seed potato tubers (44.24%) was observed from K_2 and the lowest (43.14%) from K_1.

In case of >55 mm, 45-55 mm and 28-45 mm grading, the highest (8.57%, 26.44% and 41.98%, respectively) was observed from K_1, while the lowest (8.36%, 25.28% and 40.39%, respectively) from K_2. In consideration of <28 mm grading, the highest (25.97%) was found from K_2, while the lowest (23.00%) from K_1. For Canned, Chips and French fry potato, the highest (35.56%, 31.69% and 5.25%, respectively) was observed from K_1, whereas the lowest (34.48%, 30.43% and 5.14%, respectively) from K_2. The highest firmness score of potato tubers (39.76) was found from K_1, while the lowest score (38.92) from K_2. The highest TSS in potato tubers (3.97%) was recorded from K_1, whereas the lowest (3.89%) from K_2. The highest dry matter content in potato tubers (19.83%) was recorded from K_3 while the lowest (18.74%) from K_2. The highest specific gravity of potato tubers (1.090) was found from K_3 and the lowest (1.043) from K_2. The highest starch content in potato tubers (14.81%) was observed from K_3, whereas the lowest starch content (13.63%) from K_2. The highest vitamin C content in potato tubers (22.45 mg 100 g^{-1}) was observed from K_1, while the lowest (22.10 mg 100 g^{-1}) from K_2. The highest sugar content in potato tubers (1.245%) was found from K_3, whereas the lowest (1.191%) from K_1.

For different levels of vermicompost, the maximum days required for 1st emergence (12.80) was found from Vm_3, while the minimum days (11.89) from Vm_0. The maximum days required for 80% emergence (18.80) was observed from Vm_3, whereas the minimum days (17.33) from Vm_0. The maximum days required for harvest (98.00) was observed from Vm_0, whereas the minimum days (92.22) from Vm_3. At 30, 45, 60, 75 DAP and harvest, the tallest plant (43.72, 62.23, 77.12, 85.66 and 87.72 cm, respectively) was recorded from Vm_3, whereas the shortest plant (33.94, 51.14, 65.86, 73.51 and 74.62 cm, respectively) from Vm_0. At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (30.91, 52.18, 71.29, 76.07 and 76.87, respectively) was observed from Vm_3, while the minimum number (24.67, 43.62, 64.18, 67.16 and 68.13, respectively) from Vm_0. At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (2.76, 4.69, 6.18, 7.11 and 7.16, respectively) was observed from Vm_3, whereas the minimum number (2.18, 4.11, 5.40, 5.73 and 5.82, respectively) from Vm_0. The highest SPAD value of leaf (55.01%) was recorded from Vm_3, while the lowest (45.90%) from Vm_0. The maximum number of tubers hill^{-1} (8.33) was recorded from Vm_3, whereas the minimum number (7.20) from Vm_0.The highest weight of tubers hill^{-1} (423.64 g) was found from Vm_3, while the lowest weight (343.57 g) from Vm_0. The highest average weight of individual tuber (50.91 g) was recorded from Vm_3, while the lowest (47.72 g) from Vm_0. The highest yield of potato tubers (29.61 t ha^{-1}) was recorded from Vm_3, while the lowest yield (23.34 t ha^{-1}) from Vm_0. The highest seed potato tubers (59.87%) was observed from Vm_3, whereas the lowest (51.17%) from Vm_0. The highest non-seed potato tubers (48.83%) was found from Vm_0, whereas the lowest (40.13%) from Vm_3.

In consideration of >55 mm, 45-55 mm and 28-45 mm grading, the highest (8.85%, 27.31% and 43.26%) was found from Vm_3, whereas the lowest (7.90%, 23.56% and 37.80%) was recorded from Vm_0. In consideration of <28 mm grading, the highest (30.75%) was found from Vm_0, while the lowest (20.57%) was observed from Vm_3. In consideration of Canned, Chips and French fry potato, the highest (37.82%, 33.13% and 5.82%) was found from Vm_3, while the lowest (30.84%, 27.45% and 3.90%) from Vm_0. The highest firmness score of potato tubers (42.12) was observed from Vm_3, whereas the lowest score (35.26) from Vm_0. The highest TSS in potato tubers (4.19%) was recorded from Vm_0 and the lowest (3.53%) from Vm_3. The highest dry matter content in potato tubers (20.24%) was recorded from Vm_3, whereas the lowest (17.57%) from Vm_0. The highest specific gravity of potato tubers (1.083) was found from Vm_3, while the lowest (1.046) from Vm_0. The highest starch content in potato tubers (15.61%) was recorded from Vm_3, while the lowest (11.96%) from Vm_0. The highest vitamin C content in potato tubers (23.75mg 100 g^{-1}) was observed from Vm_3, whereas the lowest (20.13mg 100 g^{-1}) from Vm_0. The highest sugar content in potato tubers (1.323%) was found from Vm_0 and the lowest (1.119%) from Vm_3.

Due to combined effect of different sources of potassium and levels of vermicompost, the maximum days required for 1st emergence (13.00) was observed from K_1Vm_3, whereas the minimum days (11.33) from K_2Vm_0 treatment combination. The maximum days required for 80% emergence (19.33) was found from K_1Vm_3 and the minimum days (16.33) from K_2Vm_0 treatment combination. The maximum days required for harvest (99.67) was observed from K_2Vm_0, while the minimum days (91.00) from K_1Vm_3 treatment combination. At 30, 45, 60, 75 DAP and harvest, the tallest plant (45.84, 65.20, 81.06, 90.68 and 93.32 cm, respectively) was observed from K_1Vm_3, while the shortest plant (32.18, 48.48, 62.49, 68.77 and 70.02 cm, respectively) from K_2Vm_0 treatment combination. At 30, 45, 60, 75 DAP and harvest, the maximum number of leaves plant^{-1} (31.93, 54.00, 72.53, 77.67 and 78.53, respectively) was found from K_1Vm_3 and the minimum number (22.07, 41.73, 62.07, 65.13 and 66.20, respectively) from K_2Vm_0 treatment combination. At 30, 45, 60, 75 DAP and harvest, the maximum number of stems plant^{-1} (3.00, 4.93, 6.47, 7.47 and 7.53, respectively) was found from K_1Vm_3 and the minimum number (2.13, 4.07, 5.13, 5.33 and 5.40, respectively) from K_2Vm_0 treatment combination. The highest SPAD value of leaf (57.01%) was found from K_1Vm_3 and the lowest

(43.48%) from K_2Vm_0 treatment combination. The maximum number of tubers hill^{-1} (8.93) was found from K_1Vm_3, while the minimum number (6.87) from K_2Vm_0 treatment combination. The highest weight of tubers hill^{-1} (450.24 g) was observed from K_1Vm_3, whereas the lowest weight (308.24 g) from K_2Vm_0 treatment combination. The highest average weight of individual potato tubers (54.49 g) was found from K_3Vm_3, whereas the lowest (44.86 g) from K_2Vm_0 treatment combination. The highest seed potato tubers (62.49%) was found from K_1Vm_3, while the lowest (50.23%) from K_2Vm_0 treatment combination. The highest non-seed potato tubers (49.77%) was found from K_2Vm_0 and the lowest (37.51%) from K_1Vm_3 treatment combination.

For >55 mm, 45-55 mm and 28-45 mm grading, the highest (9.15%, 28.09% and 44.52%) was found from K_1Vm_3, while the lowest (7.56%, 22.75% and 36.93%) from K_2Vm_0 treatment combination. In case of <28 mm grading, the highest (32.76%) was found from K_2Vm_0, while the lowest (18.23%) from K_1Vm_3 treatment combination. For Canned, Chips and French fry potato, the highest (39.67%, 34.17% and 6.08%) was found from K_1Vm_3, whereas the lowest (29.73%, 26.59% and 3.83%) from K_2Vm_0 treatment combination. The highest firmness score of potato tubers (44.01) was found from K_1Vm_3, while the lowest score (34.65) from K_2Vm_0 treatment combination. The highest TSS in potato tubers (4.38^0 Brix) was observed from K_1Vm_0, whereas the lowest (3.45^0 Brix) from K_2Vm_3 treatment combination. The highest dry matter content in potato tubers (21.12%) was observed from K_3Vm_3 and the lowest (17.17%) from K_2Vm_0 treatment combination. The highest specific gravity of potato tubers (1.103) was recorded from K_3Vm_3, whereas the lowest (1.013) from K_2Vm_0 treatment combination. The highest starch content in potato tubers (16.34%) was recorded from K_3Vm_3, whereas the lowest (11.50%) from K_2Vm_0. The highest vitamin C content in potato tubers (24.81mg 100 g^{-1}) was found from K_1Vm_3, while the lowest (20.06mg 100 g^{-1}) from K_2Vm_0. The highest sugar content in potato tubers (1.355%) was found from K_3Vm_0, whereas the lowest (1.081%) from K_1Vm_3 treatment combination.

Conclusion:

1. Findings revealed that sources of potassium varied non-significantly for different growth parameter but significantly varied for different yield and quality attributes of potato. Among the sources of potassium, KCl and K_2SO_4 performed better than KNO_3 considering yield and quality of potato.
2. Among different levels of vermicompost 12 ton vermicompost ha^{-1} performed better but it was statistically simialr with 8 ton vermicompost ha^{-1}.
3. KCl and K_2SO_4 as a source of potassium and 8 and 12 ton vermicompost ha^{-1} produced good processing quality potato. However, in Bangladesh condition availability and economic point of view, KCl combined with 8 ton vermicompost ha^{-1} would be used for producing processing quality of potato without sacrificing yield.

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

1. For regional adaptability such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh;
2. Other management practices may be included for further study, and
3. Other sources and doses of organic and inorganic fertilizer may be used for further study to specify the specific combination.

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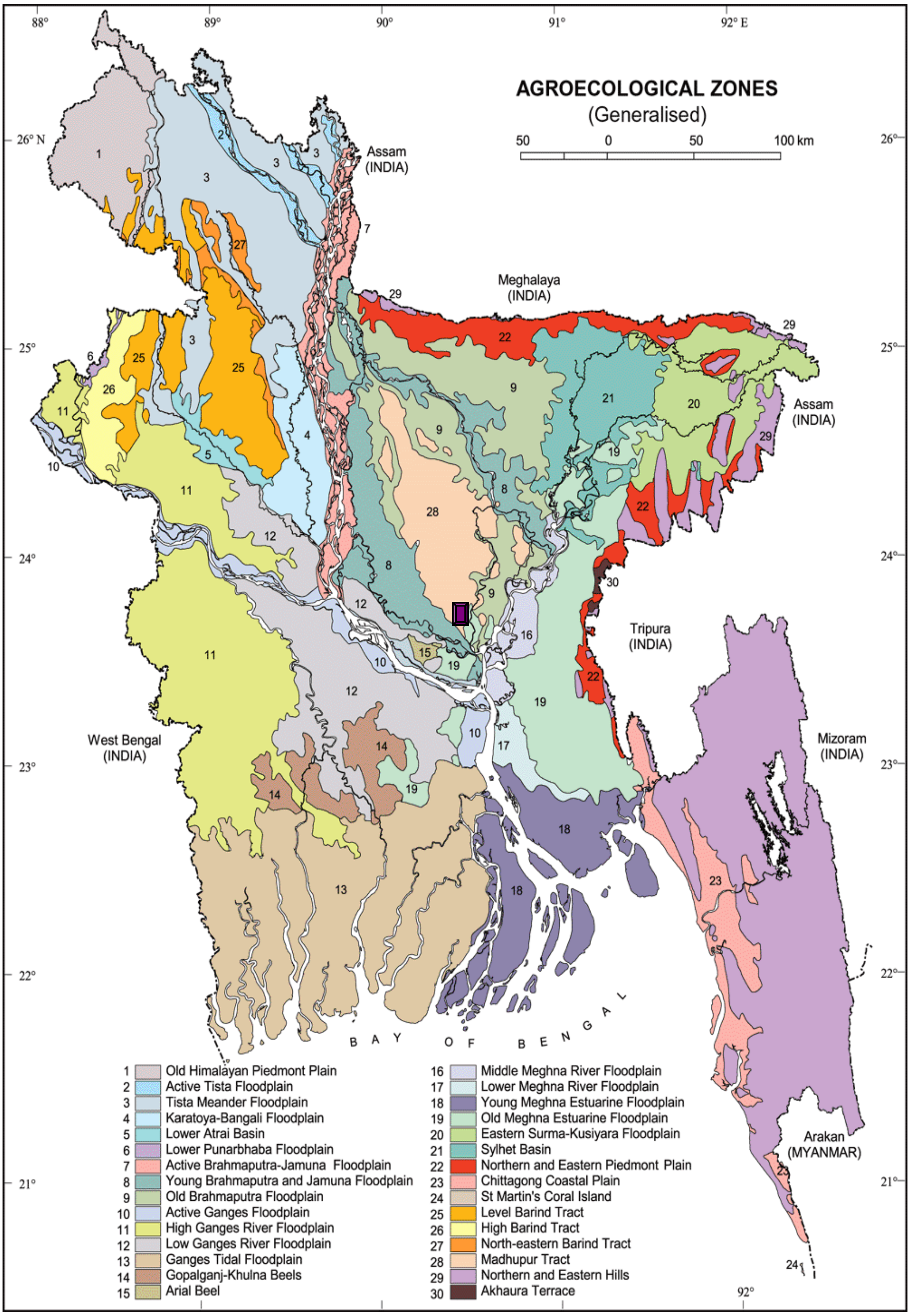
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2018 to February 2019

Month	Air temperature (^{0}C)		Relative humidity(%)	Total Rainfall(mm)	Sunshine (hr)
	Maximum	Minimum			
November, 2018	25.6	16.5	77	00	6.9
December, 2018	22.7	13.2	76	08	6.7
January, 2019	25.2	12.5	65	05	6.1
February, 2019	27.9	17.4	67	43	6.8

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

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix IV. Analysis of variance of the data on days required for 1st and 80% emergence of seedlings and harvest of potato as influenced by different sources of potassium and levels of vermicompost

Sourceofvariation	Degrees of freedom	Mean square		
		Days required for 1st emergence	Days required for 80% emergence	Days required for harvest
Replication	2	0.090	0.250	0.694
Source of potassium (A)	2	1.023NS	1.333NS	23.028NS
Error	4	0.573	0.333	14.444
Levels of vermicompost	3	1.270NS	0.546NS	55.139*
Interaction (A×B)	6	0.209NS	0.074 NS	69.695*
Error	18	0.590	0.343	15.343

NS = Non-significant; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on plant height of potato at different days after planting (DAP) and harvestas influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.049	0.566	2.424	6.140	6.576
Source of potassium (A)	2	4.346NS	8.305NS	16.283NS	16.019NS	20.745NS
Error	4	1.432	8.253	15.751	25.672	23.774
Levels of vermicompost (B)	3	178.081**	221.596**	228.167**	263.785**	301.347**
Interaction (A×B)	6	18.391*	35.084*	34.482*	50.668*	54.045*
Error	18	6.151	11.120	10.261	17.432	17.940

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} of potato at different days after planting (DAP) and harvestas influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square				
		Number of leaves plant^{-1} at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.610	0.303	3.881	0.148	0.003
Source of potassium (A)	2	4.480^{NS}	10.830^{NS}	7.338^{NS}	46.168^{NS}	50.323^{NS}
Error	4	1.235	7.613	5.366	24.291	24.667
Levels of vermicompost (B)	3	73.799**	133.016**	90.434**	141.634**	137.727**
Interaction (A×B)	6	7.052*	14.295*	22.119*	36.600*	36.962*
Error	18	2.439	3.274	7.970	19.378	16.460

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on number of stems plant^{-1} of potato at different days after planting (DAP) and harvestas influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square				
		Number of stems plant^{-1} at				
		30 DAT	45 DAT	60 DAT	75 DAT	Harvest
Replication	2	0.001	0.008	0.003	0.068	0.041
Source of potassium (A)	2	0.041^{NS}	0.041^{NS}	0.823^{NS}	0.191^{NS}	0.201^{NS}
Error	4	0.014	0.011	0.262	0.056	0.069
Levels of vermicompost (B)	3	0.561**	0.580**	1.056**	3.326**	3.381**
Interaction (A×B)	6	0.037*	0.058*	0.409*	0.295*	0.284*
Error	18	0.011	0.022	0.122	0.107	0.099

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on SPAD value of leaf, number and weight of tubers hill^{-1}, average weight of individual tuber, yield of potato, seed and non-seed potatoas influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square						
		SPAD value of leaf (%)	Number of tubers hill^{-1}	Weight of tubers hill^{-1}(g)	Average weight of individual tuber (g)	Yield of potato (t ha^{-1})	Seed potato (%)	Non seed potato(%)
Replication	2	0.506	0.018	114.314	0.647	0.334	0.546	0.546
Source of potassium (A)	2	10.980^{NS}	0.481*	11237.35**	117.629*	10.711*	3.656^{NS}	3.656^{NS}
Error	4	3.573	0.064	518.852	12.962	1.499	3.249	3.249
Levels of vermicompost	3	151.111**	2.504**	12053.10**	17.471**	72.111**	138.441**	138.441**
Interaction (A×B)	6	14.809*	0.483**	1072.018*	20.863*	5.245*	14.803*	14.803*
Error	18	3.227	0.096	323.873	3.855	1.898	5.184	5.184

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on different grading of harvested potatoas influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square			
		Grading of potato tubers (%)			
		>55 mm	45-55 mm	28-45 mm	<28 mm
Replication	2	0.261	0.262	0.055	0.762
Source of potassium (A)	2	0.137^{NS}	4.039^{NS}	7.723^{NS}	26.484^{NS}
Error	4	0.203	4.871	2.459	13.778
Levels of vermicompost (B)	3	1.619**	25.497**	54.218**	187.164**
Interaction (A×B)	6	0.487*	10.483*	7.122*	18.397*
Error	18	0.117	2.025	2.120	6.062

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix X. Analysis of variance of the data on harvested potato for canned, chips, french fry, firmness score and content of total soluble solid (TSS) as influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square				
		Category of potato tubers (%) for different uses			Firmness score (N)	Total soluble solids –TSS (^{0}Brix)
		Canned (25-35 mm)	Chips (>45 mm)	French fry (>75 mm)		
Replication	2	0.333	0.297	0.009	0.497	0.002
Source of potassium (A)	2	3.492^{NS}	4.788^{NS}	0.033^{NS}	2.129^{NS}	0.021^{NS}
Error	4	1.518	4.981	0.035	1.959	0.009
Levels of vermicompost (B)	3	88.929**	58.940**	7.045**	86.109**	0.803**
Interaction (A×B)	6	4.973*	8.724*	0.108*	10.506*	0.049*
Error	18	1.873	2.200	0.033	3.411	0.016

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix XI. Analysis of variance of the data on dry matter content, specific gravity, starch, vitamin C and sugar content in potato tubers as influenced by different sources of potassium and levels of vermicompost

Source of variation	Degrees of freedom	Mean square				
		Dry matter content in tubers (%)	Specific Gravity	Starch (%)	Vitamin C (mg 100 g^{-1})	Sugar (%)
Replication	2	0.004	0.0001	0.022	0.085	0.0001
Source of potassium (A)	2	3.638*	0.007**	4.257*	0.377^{NS}	0.009*
Error	4	0.372	0.0001	0.368	0.427	0.001
Levels of vermicompost	3	13.831**	0.002*	24.311**	24.195**	0.065**
Interaction (A×B)	6	3.949*	0.004*	0.697*	1.758*	0.008*
Error	18	0.642	0.001	0.266	0.591	0.002

NS = Non-significant; **: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix XII. Photographs of the experiment

PREPARING PLOTS

PLANTING Of TUBERS

DURING INTERCULTURAL OPERATION

DURING DATA COLLECTION

EXPERIMENTAL FIELD WITH DETAILED INFORMATION

HARVESTED POTATO