Indonesian Journal of Agricultural Science 10(2), 2009: 65-72

RESPONSE OF POTATO TO POTASSIUM FERTILIZER SOURCES AND APPLICATION METHODS IN ANDISOLS OF WEST JAVA

Nikardi Gunadi

Indonesian Vegetables Research Institute
Jalan Tangkuban Perahu 517 Lembang, PO Box 8413 Bandung 40391
Phone (022) 2786245, Facs. (022) 2786416, Email: balitsa@litbang.deptan.go.id; ngunadi@bdg.centrin.net.id

Submitted 27 November 2008; Accepted 24 June 2009

ABSTRACT

An experiment 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 (1400 m asl.), West Java from August to November 2004. 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), were arranged in a randomized complete block design with four replications. 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 (P >0.05). 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.

[***Keywords***: *Solanum tuberosum*, potassium fertilizer, potassium sulphate, potassium chloride, fertilizer application, Andisols, West Java]

INTRODUCTION

Potassium (K) is one of the sixteen essential nutrients required for plant growth and reproduction. It is classified as a macronutrient, as are nitrogen (N) and phosphorus (P). K is necessary to many plant functions, including carbohydrate metabolism, enzyme activation, osmotic regulation and efficient use of water, N uptake and protein synthesis, and translocation of assimilates (Clarkson and Hanson 1980; Lindhauer 1985). It also has a role in decreasing certain plant diseases and in improving tuber quality (Imas 1999; Cordova and Valverde 2001; McKenzie 2001; IIED 2002). Concentration of this nutrient in plants typically ranges between 1% and 4%, but it can be somewhat higher. It is absorbed from the soil solution as the K^+ ion (Thompson and Troeh 1975; Tisdale *et al*. 1985).

Plant requirements for this element are quite high. When K is present in short supply, deficiency symptoms appear in the plant. For example, in potatoes, K deficiency becomes evident by yellow to brown discoloration of lower leaves, combined with necrosis of leaf margins. K is a mobile element, which is translocated to the younger, meristematic tissues if a shortage occurs. As a result, the deficiency symptoms usually appear first on the lower leaves, progressing toward the top as the severity of the deficiency increases. Unlike N, S, P, and several other plant nutrients, K does not combine with other elements to form such plant components as protoplasm, fats, and cellulose (van der Zaag 1981; Perrenoud 1993).

Potato (*Solanum tuberosum* L.) is a high priority crop in the vegetable research in Indonesia (Balitsa 2000; Dimyati 2002). K is required in high amount by potatoes, due to their relatively poorly developed root system (Perrenoud 1983). Potato is regarded as an indicator crop for soil K availability due to its high K requirement (Roberts and Mc Dole 1985). It is difficult, however, to set universal critical ranges for soil K, because of variable growing conditions, climate, large number of available cultivars, and great differences in tuber yield in the published data. In England, for example, for high yielding potatoes the exchangeable K in the range of 100-200 mg kg^{-1} could be regarded as deficient (Birch *et al*. 1967). Recommended rates of K fertilization ranged from 150 to

300 kg ha^{-1} where potatoes are grown on K deficient soils, depending on the yield potential of the area (Roberts and Mc Dole 1985). In Indonesia, the recommended rate of K fertilization for potatoes ranges between 100 and 150 kg K_2O ha^{-1} (Rosliani *et al*. 1998).

The principal fertilizer compounds containing K are potassium chloride (KCl), potassium sulfate (K_2SO_4), potassium magnesium sulfate ($K_2SO_4.MgSO_4$), and potassium nitrate (KNO_3). In Indonesia, the common available K fertilizer is KCl, which is commonly known as muriate of potash and partially purified and sold as a fertilizer containing about 50% K (about 60% if expressed as K_2O). Although the availability of K_2SO_4 is limited in Indonesia, this K fertilizer is important especially where the S is also needed or where chlorine might be detrimental. Using K_2SO_4 usually gives a higher dry matter content than KCl. In addition, K_2SO_4 normally gives higher starch content than KCl (Perrenoud 1993).

Other important factor in applying the K fertilizer includes the application method. Banding K fertilizer near the potato seed is the most efficient method of application. However, if a soil test recommends the addition of a large quantity of K then it should be split between a pre-planting broadcast and at planting banding to avoid potential problems with salt toxicity and K leaching (Imas and Bansal 1999). Other experiments suggested that the method of application may affect the response to K fertilizer (Boyd and Dermott 1964; Webber *et al*. 1976). In addition, foliar applications of K can improve yield and tuber quality, especially in heavy clay or in sandy soils where K is not readily available for the plants (Marchand and Bourrie 1999).

In Indonesia, information on the source of K fertilizer used for the potato crop is limited, e.g. Nainggolan and Tarigan (1992). In addition, information on the application method for K fertilizer, especially the readily soluble K fertilizer such as sulfate of potash (K_2SO_4) is also limited. Therefore, it is considerably important to determine the best K fertilizer source and its application methods on the potato. The objective of the present study is to compare the effect of K fertilizer sources and application methods on potato plant growth and yield.

MATERIALS AND METHODS

The experiment was conducted at a farmer's field in Pangalengan (1400 m asl), West Java from 19 August to 25 November 2004. The soil of the experimental field is classified as Andisols. The variety of potato used was Granola, which was commonly grown by the farmers in Pangalengan, the main potato production area in West Java.

In the field experiment, treatments were arranged in a randomized complete block design with four replications. The experiment consisted of the following treatments: (1) KCl, 150 kg K_2O ha^{-1}, single application (150 KCl SA); (2) K_2SO_4, 150 kg K_2O ha^{-1}, single application (150 K_2SO_4 SA); (3) K_2SO_4, 250 kg K_2O ha^{-1}, single application (250 K_2SO_4 SA); (4) K_2SO_4, 150 kg K_2O ha^{-1}, split application (150 K_2SO_4 Sp A); (5) K_2SO_4, 250 kg K_2O ha^{-1}, split application (250 K_2SO_4 Sp A); (6) K_2SO_4, 150 kg K_2O ha^{-1}, split and foliar application (150 K_2SO_4 Sp FA); and (7) K_2SO_4, 250 kg K_2O ha^{-1}, split and foliar application (250 K_2SO_4 Sp FA).

Field plots were prepared by making furrows spaced 75 cm apart. Plant spacing within the row was 30 cm. The experimental unit was a plot of 6.0 m x 4.5 m, consisted of eight rows and 15 plants planted in each row. Therefore, the total number of potato plants was 120 per plot.

Prior to planting, chicken manure mixed with compost from mushroom media (ratio 1:1), were applied in bands at the bottom of each furrow at a rate of 25 t ha^{-1}. As basal fertilizers, urea and super phosphate (SP36) were placed over the manure at rates of 130 kg N and 252 kg P_2O_5 ha^{-1}. KCl and K_2SO_4 in the single application treatments were applied together with urea and SP36 fertilizers at planting. K_2SO_4 in the split application treatments was applied half rate at planting and the rest at 6 weeks after planting (WAP). In the split combined with foliar application treatments, K_2SO_4 was applied half rate at planting, a quarter rate at 6 WAP, and another quarter rate by spraying it to the foliar at 7, 8 and 9 WAP. At planting, the chicken manure and the basal fertilizers were put in the furrows and then covered with soil before the seed tubers were planted. In general, the potato farmers in Indonesia apply the K fertilizer only at planting, but some farmers use split application. Planting the seed tubers was done by making holes with a spacing of 30 cm between plants. Carbofuran at 15 kg ha^{-1} was applied in the furrow just before planting to control some insects in the soil such as mole cricket (*Gryllotalpa* sp.) and cut worm (*Agrotis ipsilon*). Twenty-five days after planting (DAP), 130 kg N ha^{-1} as urea was applied as top dressing.

Weeding and the first hilling-up were done at 25 DAP, at the same time as the top dressing. The second hilling-up was done at 40 DAP. Crops were sprayed regularly during the growing season using mancozeb to control late blight (*Phytophthora* *infestans*) and profenofos to control insect pests such as thrips (*Thrips palmi* Karny) and aphids (*Myzus persicae* Sulzer).

Estimates of percent ground cover of the leaf canopy were made using the method outlined by Burstall and Harris (1983). A wooden frame of 75 cm x 60 cm divided with wires into 100 rectangles was used. The frame was held over the crops at four designated sites per plot. The canopy cover measured weekly, was estimated by looking vertically down onto the grid and counting the number of rectangles more than 50% filled with green leaf. The total number of rectangles counted gave the percent ground cover. Crop cover weeks (CCW) is defined as the sum of weekly estimates of ground cover from emergence until harvest.

Plant height was measured from the soil surface to the tip of the leaves of the tallest stem when pulled erect. Plant height was based on data from 10 representative plants in each plot.

Sampling for dry matter in each plant component was conducted at 10 weeks after planting (WAP). Sampled plants were taken to the laboratory the same day and then separated into various components and oven-dried at 90°C for 2 days. The plant components in potato were leaf, stem, root, and tuber. K and S uptake by the potato plants of each treatment was also analyzed from the similar plant samples taken for dry matter at the soil laboratory of the Indonesian Vegetables Research Institute (IVEGRI). The wet ash method using sulfuric acid (H_2SO_4) and perhydrol (H_2O_2) was used to analyze both nutrients.

Final harvest was conducted at 98 DAP. The number of plant harvested in each plot was counted. Rotten tubers were also counted and weighed. Tubers were graded into categories of > 60 g, 30-60 g, and < 30 g. Tuber number and tuber weight in each weight category were determined.

To have the soil fertility status, soil samples from 12 places in the field experiment were taken before planting becoming one composite sample and analyzed for pH, organic matter, N, P and K. The analysis for soil K was done using the Morgan Wolf extraction. Evaluation of the potato quality in each treatment was done by analyzing the tuber at harvest for starch content, specific gravity, and reducing sugar content.

All parameters were analyzed by the analysis of variance using the MSTATC statistical program (MSTAT-C 1990). The treatment means were compared using Least Significant Difference (LSD) at the 5% probability level (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

The soil chemical analysis data before planting showed that the soil pH was very low (5). C and N contents were classified as high and medium, those were 3.37% and 0.39% respectively. The ratio of C/N was low, i.e. 9. P content was very high (55.6 ppm), K content was classified as high (236.8 ppm), and S content was very high (284 ppm). The cation exchange capacity (CEC) was classified as high, that was 31.28 cmol kg^{-1} (Hardjowigeno 1995).

Growth Parameter

Plant height of potato as affected by K fertilizer sources and application methods is presented in Table 1. Potatoes supplied with K fertilizer in split application and split combined with foliar application tended to have higher plant at each sampling date, although the differences were not significant from those supplied with K fertilizer in single application.

Percent canopy cover of potato as affected by K fertilizer sources and application methods is presented in Table 2. At the initial growing period, percent canopy cover of potato was not significantly affected by the sources and application methods of K fertilizer. At 9 WAP, however, percent canopy cover of potatoes supplied with K fertilizer either in split or split combined with foliar application was higher than those supplied with K fertilizer in single application.

The sources and application methods of K fertilizer affected significantly the CCW. Potatoes supplied with 250 K_2SO_4 Sp FA had the highest (488.5%) CCW (Fig. 1). The CCW of this treatment was not significantly different from those supplied with 150 K_2SO_4 Sp FA. The lowest CCW was showed by potatoes applied with 150 KCl SA.

In this experiment, maximum canopy cover was reached at 9 WAP, which differed from those of the experiment of Gunadi *et al*. (2002) with maximum canopy cover achieved at 7-8 WAP. The longer time in obtaining the maximum canopy cover in this experiment was presumably associated with the dry condition, especially in the initial growing period as also indicated in the experiment of Gunadi *et al*. (2003). In the dry season, the potatoes had a better growth due the less late blight (*P. infestans*) attack.

Dry weight (DW) of plant components of potatoes as affected by K fertilizer sources and application methods at 10 WAP is presented in Table 3. Leaf, stem, and root DW of potatoes at 10 WAP were not

Table 1. Potato plant height as affected by potassium fertilizer sources and application methods, Pangalengan, West Java, November 2004.

Treatment	Plant height (cm)					
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	9 WAP
KCl, 150 kg K_2O, single appl.	6.5	14.7	22.6	37.5	52.5	62.8
K_2SO_4, 150 kg K_2O, single appl.	7.0	14.9	23.5	38.2	53.2	62.9
K_2SO_4, 250 kg K_2O, single appl.	6.9	14.2	23.4	38.0	53.0	62.2
K_2SO_4, 150 kg K_2O, split appl.	6.7	14.2	22.8	37.6	53.6	63.1
K_2SO_4, 250 kg K_2O, split appl.	6.6	14.7	23.6	38.3	54.0	65.8
K_2SO_4, 150 kg K_2O, split & foliar	7.3	14.5	24.8	38.7	55.2	65.7
K_2SO_4, 250 kg K_2O, split & foliar	7.5	15.9	24.7	39.9	56.4	65.9
Mean	6.9	14.7	23.6	37.9	53.9	64.1
LSD (0.05)	1.4	1.6	2.0	3.6	3.9	4.3
CV (%)	13.7	7.5	5.8	7.1	3.9	4.5

WAP = weeks after planting; LSD = least significant difference; CV = coefficient of variation

Table 2. Percent canopy cover of potato as affected by potassium fertilizer sources and application methods, Pangalengan, West Java, November 2004.

Treatment	Canopy cover (%)					
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	9 WAP
KCl, 150 kg K_2O, single appl.	5.7	15.3	31.0	44.3	62.4	71.9
K_2SO_4, 150 kg K_2O, single appl.	6.3	15.9	31.9	50.0	62.6	73.0
K_2SO_4, 250 kg K_2O, single appl.	5.9	15.4	31.5	50.8	62.5	75.5
K_2SO_4, 150 kg K_2O, split appl.	5.9	16.2	31.6	48.6	61.7	83.3
K_2SO_4, 250 kg K_2O, split appl.	5.7	16.5	31.7	50.3	62.6	86.5
K_2SO_4, 150 kg K_2O, split & foliar	6.5	17.1	33.5	50.5	64.9	83.7
K_2SO_4, 250 kg K_2O, split & foliar	6.4	17.0	35.1	52.2	66.1	85.8
Mean	6.1	16.2	32.6	49.5	63.3	80.7
LSD (0.05)	1.3	2.2	3.6	3.8	6.6	8.2
CV (%)	14.1	2.2	7.4	5.2	7.0	6.9

WAP = weeks after planting; LSD = least significant difference; CV = coefficient of variation

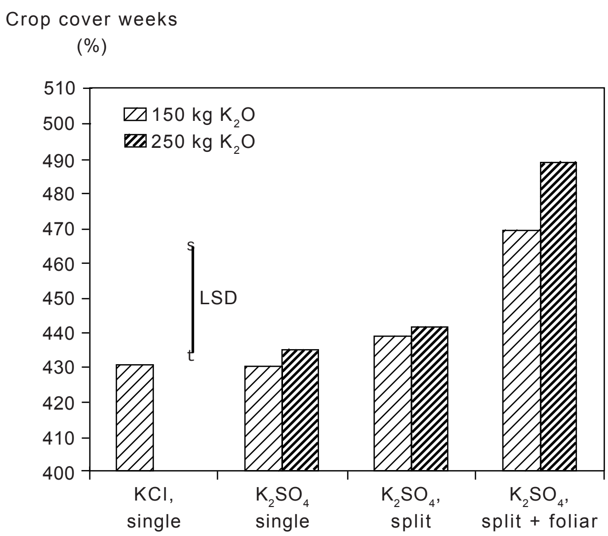

Fig. 1. Crop cover weeks of potato as affected by potassium fertilizer sources and application methods, Pangalengan, West Java, November 2004.

significantly affected by the sources and application methods of K fertilizer. However, tuber DW and total plant DW at 10 WAP were significantly affected by the sources and application methods of K fertilizer. Potatoes supplied with 250 K_2SO_4 Sp FA had significantly higher tuber DW (Table 3) and total plant DW compared to those supplied with KCl used in single application (Fig. 2).

The effect of sources of K fertilizer was significant on K uptake in potatoes at 10 WAP (Fig. 3). K uptake in potatoes supplied with K_2SO_4 at 10 WAP was significantly higher than that fertilized with KCl. However, there were no significant differences between the application methods of K fertilizer on K uptake at 10 WAP. Mean K uptake in potatoes at 10 WAP was 3879.44 mg plant^{-1}.

At 10 WAP, significant effect of sources and application methods of K fertilizer was found in terms of S uptake (Fig. 4). Potatoes under 150 or 250 K_2SO_4 Sp

Table 3. Dry weight of plant components of potatoes as affected by potassium fertilizer sources and application methods at 10 WAP, Pangalengan, West Java, November 2004.

Treatment	Dry weight (g plant^{-1})			
	Leaf	Stem	Root	Tuber
KCl, 150 kg K_2O, single appl.	22.65	9.91	1.99	66.11
K_2SO_4, 150 kg K_2O, single appl.	23.37	10.20	2.17	72.70
K_2SO_4, 250 kg K_2O, single appl.	23.82	11.49	2.07	75.80
K_2SO_4, 150 kg K_2O, split appl.	23.84	10.57	2.26	73.41
K_2SO_4, 250 kg K_2O, split appl.	25.15	11.27	2.44	78.52
K_2SO_4, 150 kg K_2O, split & foliar	24.92	11.21	2.42	75.02
K_2SO_4, 250 kg K_2O, split & foliar	26.55	13.49	2.69	88.10
Mean	24.33	11.16	2.29	75.67
LSD (0.05)	6.69	2.53	0.76	16.61
CV (%)	18.52	15.26	22.22	14.77

WAP = weeks after planting; LSD = least significant difference; CV = coefficient of variation

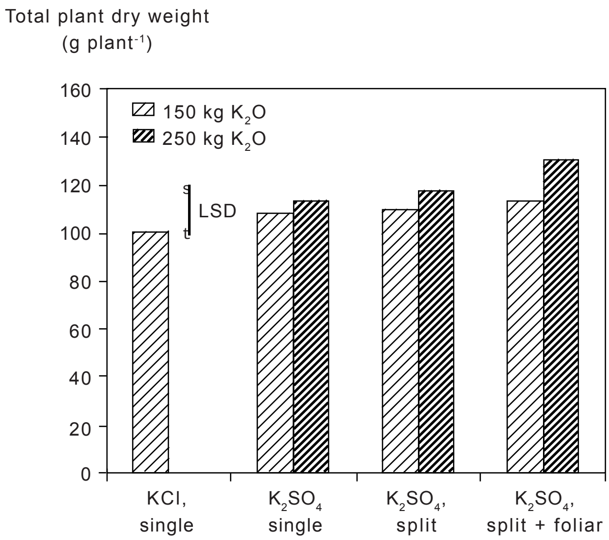

Fig. 2. Total plant dry weight of potatoes as affected by K fertilizer sources and application methods at 10 WAP, Pangalengan, West Java, November 2004.

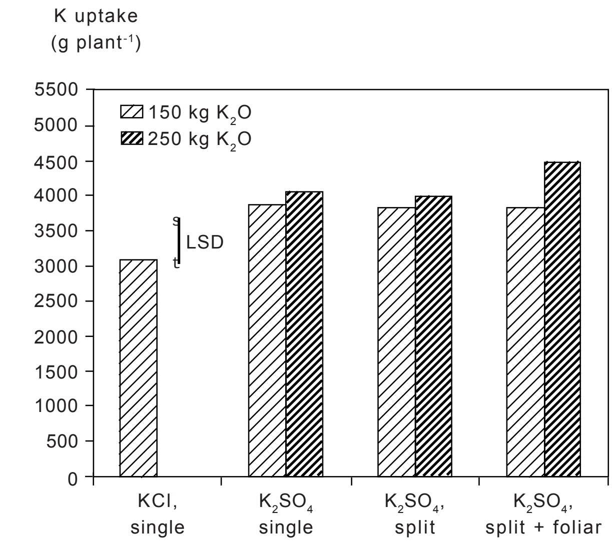

Fig. 3. Potassium uptake in potatoes as affected by K fertilizer sources and application methods at 10 WAP, Pangalengan, West Java, November 2004.

FA had significantly higher S uptake compared to those fertilized with 150 or 250 K_2SO_4 Sp A, 150 or 250 K_2SO_4 SA, KCl SA. The higher tuber DW and total plant DW at 10 WAP of potatoes supplied with K_2SO_4 either in split or split combined with foliar application was presumably associated with the higher availability and uptakes of K and S compared to those of crops fertilized with K in single application.

Yield Parameter

Tuber yield was affected significantly by the K fertilizer sources and application methods (Fig. 5). Potatoes under 250 K_2SO_4 Sp A, 150 or 250 K_2SO_4 Sp FA had significantly higher tuber yields compared to those supplied with other sources and application methods. The tuber yields of potatoes under 250 K_2SO_4 Sp A were comparable with those suplied with 150 or 250 K_2SO_4 Sp FA. In general, significant differences were not found between the two rates (150 and 250 kg K_2O ha^{-1}) in each application method. The high manure applied (25 t ha^{-1}) and the relatively high (1.50%) content of K_2O in the chicken manure presumably, diluted the differences between the two rates.

The results found here was similar with that reported by Malakouti *et al.* (1995) which showed that in terms of tuber yields, K_2SO_4 was superior than KCl. However, Bruchholz (1974) reported that chloride and non-chloride potash fertilizers have the same effects in terms of yield. Other result found by Panique *et al*. (1997) *in* Imas (1999) indicated that differences in total tuber yields were not significant between the two sources of K fertilizer studied. When K is applied up to 200 kg K_2O ha^{-1}, KCl gives a higher tuber yield than K_2SO_4, however the effect was reverse when K is applied at rates above 250 kg K_2O ha^{-1} (Perrenoud 1993), presumably because of S content in K_2SO_4.

The present study showed that using split combined with foliar application method at a rate of 150 kg K_2O ha^{-1} of K_2SO_4 was sufficient to attain an acceptable level tuber yield. 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 kg 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 combined with foliar application. This result confirmed that the use of K_2SO_4 should be split due to the solubility of this fertilizer. Marchand and Bourrie (1999) in their experiments on spinach, green pepper, tomato, and tobacco also suggested to apply K_2SO_4 as foliar application to increase the K content in the leaves for better quality crop.

Percentage of tuber at each class category as affected by K fertilizer sources and its application methods at harvest is presented in Table 4. There were no significant differences between the sources and application methods of K fertilizer treatments in terms of percent of tuber of > 60 g or 30-60 g. However, percent of tuber of < 30 g and marketable

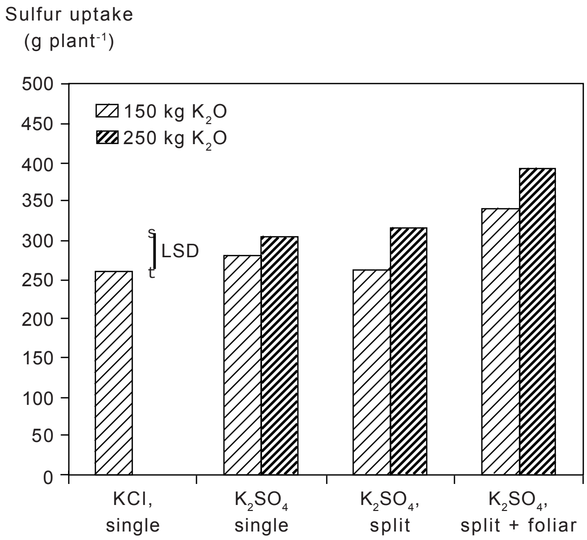

Fig. 4. Sulfur uptake in potato as affected by K fertilizer sources and application methods at 10 WAP, Pangalengan, West Java, November 2004.

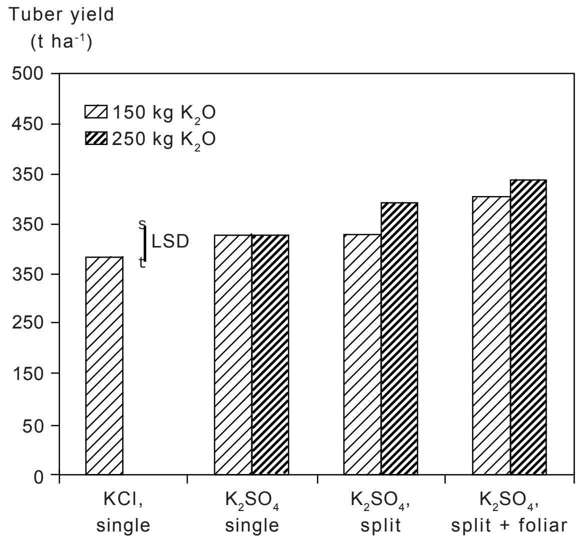

Fig. 5. Potato tuber yield as affected by K fertilizer sources and application methods at harvest, Pangalengan, West Java, November 2004.

Table 4. Percentage of potato tubers at each class category as affected by potassium fertilizer sources and application methods at harvest, Pangalengan, West Java, November 2004.

Treatment	% tuber by weight at harvest			
	> 60 g	30-60 g	< 30 g	Marketable
KCl, 150 kg K_2O, single appl.	58.9	21.9	19.2	80.8
K_2SO_4, 150 kg K_2O, single appl.	60.0	22.3	15.6	82.3
K_2SO_4, 250 kg K_2O, single appl.	60.8	24.1	17.1	84.9
K_2SO_4, 150 kg K_2O, split appl.	59.1	24.0	16.9	83.3
K_2SO_4, 250 kg K_2O, split appl.	62.4	25.1	12.5	87.5
K_2SO_4, 150 kg K_2O, split and foliar	60.7	25.1	14.2	85.8
K_2SO_4, 250 kg K_2O, split and foliar	60.7	26.0	13.2	86.8
Mean	60.4	24.1	15.5	84.5
LSD (5%)	4.4	5.3	4.2	4.2
CV (%)	8.9	14.7	18.4	7.4

LSD = least significant difference; CV = coefficient of variation.

tuber were affected by K fertilizer source and application methods. Potatoes under 250 K_2SO_4 Sp A, 150 or 250 K_2SO_4 Sp FA had significantly lower percent of small tuber (< 30 g) compared to those supplied with other source and application method treatments. In terms of marketable tubers, potatoes under 250 K_2SO_4 Sp A, 150 or 250 K_2SO_4 Sp FA had significantly higher marketable tubers than those supplied with other source and application method treatments. Mean marketable tubers of potatoes under 250 K_2SO_4 Sp A, 150 and 250 K_2SO_4 Sp FA were 87.5%, 85.8% and 86.8%, respectively.

Other characteristic determined the quality of potato tuber is specific gravity. In this experiment, the specific gravity of potatoes under 250 K_2SO_4 Sp A, 150 and 250 K_2SO_4 Sp FA were 1.040, 1.042 and 1.041, respectively, higher than those supplied with other sources and application methods (Fig.6). The differences, however, were not significant.

Although the data were not statistically analyzed, the reducing sugar content was also decreased with the use of K_2SO_4 compared to KCl (Table 5). The mean reducing sugar content under K_2SO_4 and KCl treatments were 0.108% and 0.508%, respectively.

In terms of starch content, potatoes supplied with K_2SO_4 tended to have higher starch content compared to those fertilized with KCl. The mean starch contents of potatoes supplied with K_2SO_4 and KCl were 6.625% and 6.011%, respectively.

As agreed with the results of the previous experiment (Gunadi *et al*. 2003), although no significant differences were found, the use of K_2SO_4 at a rate of 250 kg K_2O ha^{-1} in split application, potatoes sup-

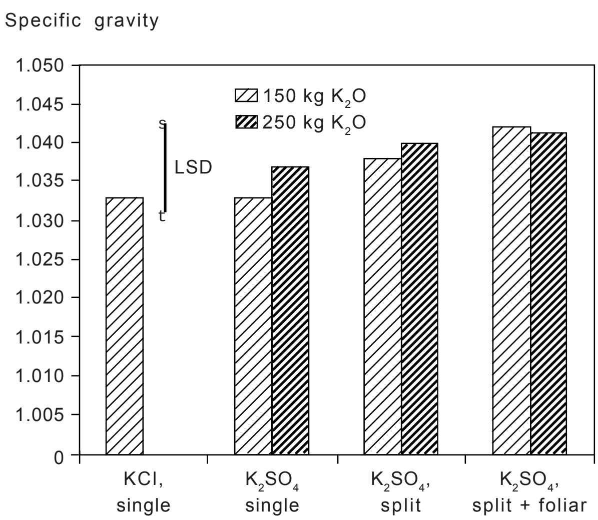

Fig. 6. Specific gravity of potato as affected by potassium fertilizer sources and its application methods at harvest, Pangalengan, West Java, November 2004.

Table 5. Reducing sugar content and starch content of potato as affected by potassium fertilizer sources and application methods at harvest, Pangalengan, West Java, November 2004.

Treatment	Reducing sugar content (%)	Starch content (%)
KCl, 150 kg K_2O, single appl.	0.508	6.011
K_2SO_4, 150 kg K_2O, single appl.	0.054	7.831
K_2SO_4, 250 kg K_2O, single appl.	0.029	7.963
K_2SO_4, 150 kg K_2O, split appl.	0.176	8.073
K_2SO_4, 250 kg K_2O, split appl.	0.191	6.011
K_2SO_4, 150 kg K_2O, split and foliar	0.174	7.281
K_2SO_4, 250 kg K_2O, split and foliar	0.136	9.218
Mean	0.181	7.484

plied with K_2SO_4 at rates of 150 kg K_2O ha^{-1} or 250 kg K_2O ha^{-1} in split combined with foliar application had higher specific gravity compared to the use of K fertilizer in single application (Fig. 6).

Although the data were not statistically analyzed, reducing sugar content was decreased with the use of K_2SO_4 compared to KCl (Table 5). This trend was similar to other research studies. Perrenoud (1993) reported that the use of K_2SO_4 had a positive effect on decreasing the reducing sugar content. Similar to data on other tuber quality, starch content in this experiment was increased with the use of K_2SO_4, although the data were not statistically analyzed. The result was agreed with other research studies. Working with solution, Header (1976) *in* Perrenoud (1993) showed that the effect of SO_4 in increasing starch content was mainly due to improved translocation of metabolites to the tubers, thus, 24 hours after applying $^{14}CO_2$, 12% of the assimilated label was found in Cl tubers compared with 39% in SO_4 tubers. Other reports indicated that the use of K_2SO_4 was preferred especially for tobacco and potato for good quality of products (Thompson 2002; Vitosh 1990; Brady 1984; Thompson and Troeh 1975).

CONCLUSION

Potatoes supplied with K_2SO_4 either in split application or split combined with foliar application had significantly higher percent canopy cover, crop cover weeks, tuber dry weight, and total plant dry weight than those applied with K fertilizer in single application. Potatoes supplied with K_2SO_4 had a higher tuber yield compared to those fertilized with KCl, especially when applied in 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 kg to 250 kg K_2O ha^{-1} when using single application. It is therefore suggested that the application of K_2SO_4 for potatoes should be split combined with foliar application. The use of K_2SO_4 had a positive effect on increasing specific gravity, decreasing the reducing sugar content, and increasing the starch content.

REFERENCES

Balai Penelitian Tanaman Sayuran. 2000. Analisis Komoditas (Kentang, Cabai, Tomat dan Bawang Merah). Rapat Kerja Pusat Penelitian Hortikultura dan Aneka Tanaman, Segunung, 28-30 Agustus 2000. Balai Penelitian Tanaman Sayuran, Pusat Penelitian Hortikultura dan Aneka Tanaman.

Birch, J.A., J.R. Deyine, M.R.J. Holmes, and J.D. Whitear. 1967. Field experiments on the fertilizer requirements of maincrop potatoes. J. Agric. Sci., Cambridge 69: 13-24.

Boyd, D.A. and W. Dermott. 1964. Fertilizer experiments on maincrop potatoes 1955-1961. J. Agric. Sci., Cambridge 63: 249-263.

Brady, N.C. 1984. Fertilizers and fertilizer management. p. 589-626. *In* N.C. Brady (Ed.). The Nature and Properties of Soils, Ninth Edition. MacMillan Publ. Co.y, New York.

Bruchholz, H. 1974. Soil and crop response to long-term potash fertilization. p. 111-116. Proc. 10th Congress of International Potash Institute. Bern.

Burstall, L. and P.M. Harris. 1983. The estimation of percentage light interception from leaf area index and percentage ground cover in potatoes. J. Agric. Sci., Cambridge 100: 241-244.

Clarkson, D.T. and J.B. Hanson. 1980. The mineral nutrition of higher plants. Ann. Rev. Plant Physiol. 31: 239-298.

Cordova, J. and F. Valverde. 2001. Potato response to potassium application in Volcanic soils. Better Crops International 15(1): 16-17.

Dimyati, A. 2002. Research priorities for potato in Indonesia. Progress in Potato and Sweetpotato Research in Indonesia. p. 15-19. *In* K.O. Fuglie (Ed.). Proc. the CIP-Indonesia Research Review Workshop, Bogor, Indonesia, 26-27 March 2002.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. Second edition. An International Rice Research Institute Book. A Wiley-Interscience Publication. John Wiley & Sons, New York-Chichester-Brisbane-Toronto-Singapore. p. 188-206.

Gunadi, N., W. Adiyoga, and A. Hidayat. 2002. Potassium sulfate (K_2SO_4) as a source of potassium (K) fertilizer in potato, shallot, tomato and hot pepper. Research Project Report. Collaborative research between the Research Institute for Vegetables (RIV), the Central Research Institute for Horticulture (CRIH) and the Sulfate of Potash Information Board (SOPIB).

Gunadi, N., W. Adiyoga, and A. Hidayat. 2003. Effect of source and rate of potassium fertilizer on potato, shallot and cabbage. Research Project Report. Collaborative research between the Indonesian Vegetables Research Institute (IVEGRI), the Indonesian Center for Horticulture Research and Development (ICHORD) and the Sulfate of Potash Information Board (SOPIB).

Hardjowigeno, S. 1995. Ilmu Tanah. Edisi Revisi. Akademika Pressindo, Jakarta. hlm. 126.

IIED (International Institute for Environment and Development). 2002. Potash Case Study. Information supplied by the International Fertilizer Industry Association. http://www.iied.org./mmsd/mmsd_pdfs/obs_ifa.pdf. [14 March 2003].

Imas, P. 1999. Integrated nutrition management in potato. Paper presented at the Global Conference on Potato, December 1999, New Delhi, India.

Imas, P. and S.K. Bansal. 1999. Potassium and Integrated Nutrient Management in Potato. Abstracts of the Global Conference on Potato, 6-11 December, 1999, New Delhi, India. 105 pp.

Lindhauer, M.G. 1985. The role of potassium in the plant with emphasis on stress condition (water, temperature, salinity). p. 95-113. Proceedings of the Potassium Symposium. Pretoria, October 1985. Department of Agriculture and Water Supply, International Potash Institute and Fertilizer Society of South Africa.

Malakouti, M.J., A. Ziaeyan, Z. Khademi, M.R. Balali, M. Shahabian, M. Basirat, H. Rezaee, M.H. Davoudi, S. Samavat, S. Manouchehri, and M. Kafi. 1995. Effects of rates and sources of potassium on some field and horticultural crops in Iran. http://www.cf.uwex.edu/ces/pubspdf/A2521.pdf. [14 March 2003].

Marchand, M. and B. Bourrie. 1999. Crop yield and quality response to different application methods of potash fertilizers. Regional Symposium on Balanced Fertilization and Crop Response to Potassium. SWRI-Teheran, Iran, 15-18 May 1999.

McKenzie, R. 2001. Potassium fertilizer application in crop production. http://www.agric.gov.ab.ca/universal-pages/includes/docheader.map. [14 March 2003].

MSTAT-C. 1990. Micro Computer Statistical Program for Experimental Design and Analisys. Russell Freed (Ed.). MSTAT/Michigan State University. East Lansing MI.

Nainggolan, P. dan D. Tarigan. 1992. Pengaruh sumber dan dosis pupuk kalium terhadap hasil dan mutu umbi kentang. J. Hort. 2(3): 16-18.

Perrenoud, S. 1983. Potato: Fertilizer for yield and quality. IPI Bull. No. 8. International Potash Institute, Berne, Switzerland.

Perrenoud, S. 1993. Fertilizing for higher yield potato. IPI Bull. No. 8. 2nd Ed. International Potash Institute, Berne, Switzerland.

Roberts, S. and R.E. McDole. 1985. Potassium nutrition of potatoes. p. 800-818. *In* R.S. Munson (Ed.). Potassium in Agriculture. ASA-CSSA-SSSA, WI.

Rosliani, R., N. Sumarni, and Suwandi. 1998. Pengaruh sumber dan dosis pupuk N, P, dan K pada tanaman kentang. J. Hort. 8(1): 988-999.

Thompson, B. 2002. Efficient fertilizer use - potassium. http: //www.back-to-basics.net/efu/pdfs/potassium.pdf. [12 March 2003].

Thompson, L.M. and F.R. Troeh. 1975. Soils and Soil Fertility. Tata McGrawHill Publ. Co. Ltd., New Delhi. p. 289-311.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil and fertilizer potassium. p. 249-291. *In* Soil Fertility and Fertilizers. Macmillan Publ. Co., New York.

Van der Zaag, P. 1981. Soil Fertility Requirements for Potato Production. Technical Information Bulletin 14, International Potato Center (CIP), Lima, Peru.

Vitosh, M.L. 1990. Potassium fertilizer. N-P-K Fertilizers. Extension Bulletin E-896. Michigan State University Extension. http://www.msue.msu.edu./msue/imp/modf1/06109729.html. [14 March 2003].

Webber, J., D.A. Boyd, and A. Victor. 1976. Fertilizers for maincrop potatoes on magnesian limestone soils. Experiments in Yorkshire 1966-71. Experimental Husbandry 31: 80-90.