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Short note

Potato response to potassium application rates and timing under semi-arid conditions

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Abstract: A two-year experiment (2004-2005) was conducted at Tal Amara Research Station in the Bekaa Valley of Lebanon to evaluate the influence of progressive application of K rates and application timing on yield, yield components and tuber quality of potato (*Solanum tuberosum* L. cv. Agria). Four levels of potassium (0 (K_0), 75 (K_{75}), 150 (K_{150}), and 225 (K_{225}) kg K_2O ha^{-1}) and two application timings (tuber initiation and tuber bulking stages) were used in a split-plot design. The progressive application of potassium fertilizer from 0 to 225 kg K_2O ha^{-1} significantly affected the yield and yield components of potato. In both years, small grade tubers and aggregate tuber yield increased quadratically with increasing K application rates up to 150 kg K_2O ha^{-1}, reaching a plateau thereafter, showing luxury consumption of the nutrient at 225 kg K_2O ha^{-1}. In 2004 when averaged over K application rates, large and medium grade tubers and aggregated tuber yield were 120%, 22%, and 12% greater, respectively, with K application at tuber bulking than at tuber initiation. A similar trend was also observed in 2005, when the small grade tubers and aggregate tuber yield were 20% and 12% higher, respectively, with K application at tuber bulking than at tuber initiation stage. Finally, no significant difference among treatments was observed for tuber dry matter (avg. 19.8%) and specific gravity (1.08 g cm^{-3}).

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the major crops contributing to the world's food requirement because it is a rich source of starch, having protein of high biological value (Eppendorfer and Eggum, 1994). In Lebanon, potato occupies an area of 19,700 ha with a total production of 460,000 t, but average yield is only 23 t ha^{-1}, which is much below the crop's potential productivity. Such a low yield seems to be due to the imbalance in nutrients applied for the agricultural production of this crop.

Owing to the current trend of intensive cropping in Lebanon, soils have developed multi-nutrient deficiencies. Farmers usually diagnose and correct the deficiencies of nitrogen (N) and phosphorus (P), but often neglect the effect of deficiencies of other essential macronutrients such as potassium (K). In addition to N and P, potato is a heavy remover of soil potassium and its response to potassium varies with variety, source and method of potassium fertilizer application (Sharma and Sud, 2001; Kumar *et al.*, 2007; Abd El-Latif *et al.*, 2011).

Since biomass and bulking rate of potato tubers are positively affected by synthesis and accumulation of starch, K plays a key role in this regard as it is the most efficient monovalant cation that stimulates the activity of the starch synthase enzyme, catalyzing the incorporation of simple glucose molecules into complex molecules of starch (Moinuddin *et al.*, 2004). Starch accumulation is coupled with cell and tissue growth of the tubers as K enhances the overall growth of the plants (Singh and Singh, 1996), and facilitates the translocation of assimilates to the sinks/tubers (Moinuddin *et al.*, 2005), which could ultimately increase the tuber bulking capacity and, thereby, its biomass and yield. Thus, potato removes large quantities of K and other soil nutrients, particularly N and P, in a short period coupled with a high rate of dry matter production (Perrenoud, 1993; Singh and Trehan, 1998). An optimum K level, along with optimum levels of N and P would, therefore, be required to exploit the full genetic potential of the crop and achieve an improved level of tuber yield and quality.

In spite the efforts aimed at optimizing potato response to K fertilization, little has been done on the time of K application for potato farming. This study, conducted in the Central Bekaa Valley of Lebanon, aims at assessing potato response to increasing in-season potassium rates (four progressive rates of K) applied at different times of tuber

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growth (tuber initiation and tuber bulking stages) and to depict the optimal rate to achieve target yield.

2. Materials and Methods

Experimental site

Field experiments were conducted from April to August during the 2004 and 2005 growing years at Tal Amara Research Station in the Central Bekaa Valley of Lebanon (33º 51' 44'' N lat., 35º 59' 32'' N long., 905 m a.s.l). The details of the experimental site have been described elsewhere (Karam *et al*., 2003, 2005, 2006, 2007, 2009 a,b, 2011). Tal Amara has a well-defined hot and dry season from May to October and very cold conditions for the remainder of the year. Average seasonal rainfall is 592 mm, with 95% of the rain occurring between November and March, and a maximum of 145 mm in January. Historical data indicate no rain occurrence at Tal Amara from June to September. Rainfall amounts during the growing period were 35 and 25 mm during 2004 and 2005, respectively. Soils of the experimental site were deep, non-calcareous, clay Eutric Cambisols with an average bulk density of 1.2 g cm^{-3}. Soil chemical and physical properties were: available N content 45.5 g kg^{-1}, available P content 17.0 g kg^{-1}, and available K content 11.5 g kg^{-1}, organic matter content 1.2% and pH 7.9.

Crop management, K-treatments and experimental design

Potato (*Solanum tuberosum, L.*) seeds of cultivar Agria were sown under field conditions on 5 April 2004 and 11 April 2005. The soil was plowed and disked each year in anticipation for bed preparation. In both years, seeds were planted in a conventional "hill" system, where single soil beds were separated by relatively deep furrows spaced 70 cm apart, giving a theoretical plant density of 70000 plants ha^{-1}. The experiments were conducted under optimum irrigation conditions in both years. At planting, the soil surface was thoroughly moistened using a sprinkler irrigation system at the application rate of 4.5 mm h^{-1}. When plants reached 8 to 10 cm in height (two weeks after emergence), a drip irrigation system was installed along the furrows. The drip system consisted in polyethylene (PE) distribution lines, 16 mm in diameter, 40 cm spaced drippers, delivering each 4 L h^{-1} at 1 bar of head pressure. Experiments were set up in a split plot design (main plot: potassium application rate; sub-plot: application timing). The trial covered four levels of potassium (0 (K_0), 75 (K_{75}), 150 (K_{150}), and 225 (K_{225}) kg K_2O ha^{-1}) and two application times (tuber initiation and tuber bulking stages), with five replications. Each experimental unit consisted of six rows, 5 m in length. In both years, preplant fertilizer was broadcast (150 kg·ha^{-1}; 17N - 17P -17K) and incorporated into the soil. Moreover, a fertilizer dose of 144 kg N and 96 kg P_2O_5 ha^{-1} was applied in two splits after planting (35 days after planting, DAP) and at tuber initiation (60 DAP) uniformly to all the plots to assure rigorous shoot development. Potassium was applied as K_2O (0-0-46) in one split at tuber initiation (60 DAP) and tuber bulking (80 DAP) stages in four application rates with irrigation water. The experiments were concluded on 3 August 2004 (120 days after planting) and on 8 August 2005 (119 days after planting).

Data collection

After harvest, the tuber yield was grouped into three grades, grade 1 (200-400 g), grade 2 (85-200 g) and grade 3 < 85 g. The grade-wise and aggregate tuber yields were recorded. Tubers were dried in a forced-air oven at 80°C for 72 h and weighed to determine the tuber dry matter (DM). Tuber specific gravity (tuber weight in air/tuber weight in water) (Dunn and Nylund, 1945) was determined on subsamples of acceptable tubers.

Statistical analysis

All data were statistically analyzed by ANOVA using the SPSS software package (SPSS 10 for Windows, 2001). Duncan's multiple range test was performed at p=0.05 on each of the significant variables measured.

3. Results and Discussion

In experiment 1 (2004), small grade tubers and aggregate tuber yield were significantly affected by K application rates, whereas large and medium grade tubers and aggregate tuber yield were highly influenced by K application timing, with no 'K rates x K timing interaction' (Table 1). While in experiment 2 (2005), small grade tubers and aggregated tuber yield were significantly influenced by K application rates, K application timing, with no significant 'K rates x K timing interaction' (Table1). In both years, no significant difference among treatments was observed for tuber dry matter (avg. 19.8%) and specific gravity (1.08 g cm^{-3}) (Table 1). These results on tuber quality (i.e. dry matter and specific gravity) are consistent with the findings of Davenport and Bentley (2001) who observed no response in tuber quality, mainly specific gravity, in response to increasing K rates. In contrast, others have reported that excess K fertilizer reduces dry matter content and specific gravity of tubers (Westermann *et al.,* 1994 a, b). Explanations for this disagreement could be the different environments in which the plants were grown, and variations between potato genotypes in response to potassium application rates.

In 2004 when averaged over K application rates, large and medium grade tubers and aggregated tuber yield were 120%, 22%, and 12% greater, respectively, with K application at tuber bulking than at tuber initiation. A similar trend was also observed in 2005, when the small grade tubers and aggregate tuber yield were 20% and 12% higher, respectively, with K application at tuber bulking than at tuber initiation stage (Table 1). In both years, irrespective of K application timing, the highest small grade tubers yield was recorded with K application rates of 150 kg K_2O ha^{-1} (avg. 30 and 33 t ha^{-1}, in 2004 and 2005 respectively), whereas the highest aggregate tuber yield was observed at both K_{150} and K_{225} with no significant difference observed between the two K application rates followed by K_{75} and finally K_0 treatment.

In both experiments, aggregate tuber yield increased quadratically with increasing K application rates up to 150 kg K_2O ha^{-1}, reaching a plateau thereafter, indicating the luxury consumption of the nutrient at 225 kg K_2O ha^{-1} (Table 1). Significant increase in tuber yield of potato as a result of K application is well documented (Cordova and Valverede, 2001; Singh *et al*., 2001; Tawfik, 2001; Umar and Moinuddin, 2001; Moinuddin *et al*., 2004, 2005). In fact, potato has a higher potassium requirement for optimum production compared to cereals, pulses, oilseeds, and other commercial crops and produces much more dry matter in short growth duration. It produces large amounts of starch due to K-mediated carbohydrate metabolism (Perrenoud, 1993; Singh and Trehan, 1998). In addition, it helps in efficient translocation of photoassimilates to the developing sinks/tubers (Beringer, 1978) and enabling the plants to fully utilize applied N and P fertilizers (Mengel and Kirkby, 1987). Thus, K helps the potato tubers to attaine large size and heavier weight. This was evident in the current study, as we observed a progressive increase in aggregate tuber yield. These results are consistent with the findings of Moinuddin *et al*. (2004, 2005) and Abd El-Latif *et al*. (2011) who showed an increase in tuber yield with a progressive application of K fertilizer from 0 to 225 kg K_2O ha^{-1} (Moinuddin *et al*., 2004, 2005) and from 72 to 120 kg K_2O $fed.^{-1}$ (Abd El-Latif *et al*. 2011). Moreover, in line with our results, Singh *et al*. (1997) reported that an increase in K application rates resulted in an increase in the yield of small-grade tubers.

To summarize, we can conclude that the progressive application of potassium fertilizer from 0 to 225 kg K_2O ha^{-1} significantly affected the yield and yield components of potato. In both experimentation years, small grade tubers and aggregate tuber yield increased quadratically with in-

Table 1 - Effects of potassium application rates and K application timing on grade-wise and aggregate tuber yield, tuber dry matter and specific gravity of potato plants grown in 2004 and 2005

Year	K timing	K rate	Grade-wise tuber yield (t ha^{-1})			Aggregate yield	Tuber dry matter	Specific gravity
		Kg K_2O ha^{-1}	Grade 1	Grade 2	Grade 3	t ha^{-1}	%	g cm^{-3}
2004	Tuber initiation Stage	0	0.6	30.7	19.9	51.2	20.0	1.078
		75	0.3	23.4	28.1	51.8	19.8	1.079
		150	0.9	24.2	28.9	54.0	19.5	1.077
		225	0.2	26.0	29.4	55.6	20.2	1.081
	Tuber bulking Stage	0	1.0	27.4	25.5	53.9	19.5	1.077
		75	1.7	30.8	24.3	56.8	19.2	1.075
		150	0.4	33.0	31.1 a	64.5	20.0	1.079
		225	1.3	36.5	25.2	63.0	20.0	1.080
Significance [z]	K rate		NS	NS	**	**	NS	NS
	K timing		*	*	NS	*	NS	NS
	K rate x K timing		NS	NS	NS	NS	NS	NS
2005	Tuber initiation Stage	0	0.8	29.1	22.7	52.6	19.8	1.078
		75	1	27.1	26.2	54.3	19.5	1.077
		150	0.6	28.0	30	58.6	19.8	1.078
		225	0.8	31.2	27.3	59.3	20.1	1.081
	Tuber bulking Stage	0	0.9	28.2	27.3	56.4	19.7	1.077
		75	1.3	29	31.4	61.7	19.3	1.076
		150	0.5	31.0	36	66.5	19.9	1.079
		225	1	33.9	32.8	67.7	20.0	1.080
Significance [z]	K rate		NS	NS	*	**	NS	NS
	K timing		NS	NS	*	*	NS	NS
	K rate x K timing		NS	NS	NS	NS	NS	NS

[z] NS [*, **, ***] Non significant or significant at $P < 0.05$, or 0.01 respectively.

creasing K application rates up to 150 kg K_2O ha^{-1}, reaching a plateau thereafter, showing luxury consumption of the nutrient at 225 kg K_2O ha^{-1}, indicating the detrimental effect of over fertilization. The results also demonstrated that K application during tuber bulking stage was more effective in terms of yield and yield components, and not in terms of quality, than at tuber initiation stage.

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