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REVIEW ARTICLE

Response of irish potato (*Solanum tuberosum* L.) to the application of potassium fertilizer in acidic soil: A review

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In Ethiopia, it has long been assumed that Ethiopian soils are high in K and that there is no need for its application, based on a 40-year-old research conclusion. However, due to continual mining, leaching loss, soil erosion, and other factors, shortage in K is likely to develop in some soils over time. Soil acidity is a severe concern for crop production in the highland's areas of southern Ethiopia, and it is usually linked to K shortage. Many experts have stated that the results of soil chemical analysis data of samples revealed that the available K content for plant growth and development is fairly low. According to various researchers, the application of K enhanced potato tuber yields significantly when compared to the control in acidic highland soil.

Keywords: Potato tuber, Potassium fertilizer, Soil acidity, Phosphorus fertilizer K Deficiency.

Introduction

Potassium (K) is one of the most important elements for plant growth and development. It is crucial for enzyme activation, photosynthesis, starch production, nitrate reduction, and sugar breakdown (Safeguard et al., 2004). Potassium is especially crucial for helping plants adapt to environmental stresses including drought, improve winter hardiness, and confer frost, disease, and insect pest tolerance (Brady and Weil, 2002). As a result, its deficit in soil reduces agricultural output significantly, and crops affected by K deficiency are more sensitive to disease and pests, frost damage, and have low yield and quality (Umar and Moinuddin, 2001). In most cases, K shortage is linked to soil acidity in places with significant rainfall and long periods of no crop output. As a result of the leaching and mining of most cations, including K, lack of such critical elements may occur (Potash Institute, 1979; Getachew, 2009). Based on the research finding of Murphy (1968) some 40 years ago, there was a prevalent perception in Ethiopia that Ethiopian soils are rich in K and that there was no need for its application. However, due to continual mining, leaching loss, soil erosion, and other factors, shortage in K is likely to develop in some soils over time. Soil acidity is a severe concern for crop production in several highlands of southern Ethiopia, such as the Chencha and Hagereselam areas, and it is usually related with K shortage. Soil chemical analysis data from subsets of these locations revealed that they have accessible K contents of 11.2 and 19 mg/L, respectively. which is quite low for plant growth and development (Jones, 2001).

Potatoes are currently cultivated on around 74,935 hectares, yielding a projected total tuber production of 863,348 tons. Statistical Authority of the United Nations (CSA, 2013). This means that the country's average production is only 17.4 tha^{-1}, but small-holder potential is predicted to be over 25 tha^{-1}. Despite the fact that several enhanced potato varieties were created and made available to users to fill the gap, their full potential could not be realized, due in part to a lack of effective nutrient management procedures. Furthermore, potato is grown on nitisols, which are soils that are deprived of important natural nutrients and have a problem with soil acidity.

Soil acidity and K deficiency are severe crop production difficulties in the highlands of western and southern Ethiopia, where nitisol dominates. Despite the administration of appropriate nitrogen and phosphate fertilizers, the lack of potassium in Ethiopian highland soils has hampered output (Wassie Haile, 2009). However, potassium fertilizer application is not used in these places. Farmers, on the other hand, put wood ash on their plots to boost productivity (Wassie Haile, 2009).

Objective

To review on response of Irish potato to the application of potassium fertilizer those different researchers applied on various soil types and in number of agro ecological zones.

Literature Review

Causes for the occurrence of K deficiencies

Soil erosion caused by torrential rainfall along, which K is removed, deforestation, continuous mining of K through crop export, leaching of cations including K, and other possible reasons could be the cause of K deficiencies in some highland areas of southern Ethiopia and possibly in other similar areas of Ethiopia (Wassie et al., 2009).

In Kenya's cold highlands, the main constraint to potato output is the rapid loss of soil fertility caused by continuous cultivation without appropriate replenishment of mined nutrients (Kiiya et al., 2006). Farmers repeatedly plant crops on the same land due to short land sizes, using intensive cropping techniques that primarily comprise double and relay cropping of diverse crops without a fallow period (Kaguongo et al., 2008).

Intensive cropping, complete crop residue removal, widespread use of no-K fertilizers (DAP and urea), and the absence of mineral K fertilizer in the study area's soils may have resulted in K depletion (Laekemariam Fanuel et al., 2016).

Influence of K on growth parameters

Plant height

According to Habtam Setu et al., (2018), potassium application increased the height of potato plants substantially. The plant height grew by around 23% when the potash rate was increased from zero to 100 kg K_2O ha^{-1}. Plant height was not considerably influenced beyond a rate of 100 kg K_2O ha^{-1} (Table 3). This demonstrates that potassium leads to enhanced cell division and elongation, resulting in increased canopy development.

Dry biomass

Increasing the potassium rate resulted in a considerable increase in the crop's aboveground, underground, and total dry biomass yield. When compared to the control treatment, all potassium fertilizer treatments produced significantly more above- and subterranean biomass, as well as total biomass; however, there was no significant biomass production in the 200 and 300 kg K_2O ha^{-1} treatments.

Leaf Area Index (LAI)

The leaf area index of the crop grew by roughly 34% when potassium fertilization was raised from nil to 100 kg. When the K_2O concentration was increased to 100 and 200 kg $ha-^{1}$, the leaf area rose by 49 and 57 percent, respectively, compared to the control. However, the leaf area indexes measured at 100 and 200 kg K_2O ha^{-1}, as well as 200 and 300 kg K_2Oha^{-1}, were statistically equal (Table 3).

Increased potassium application resulted in higher leaf area indices, which could be attributed to increased growth of vegetative plant parts due to the simulative effect of increased potassium supply on assimilate synthesis and meristem tic growth of tissues, which could have resulted in more leaves and higher leaf area indices.

Table 1. Growth parameters of potato as influenced by potassium application at Assosa.

Treatment	P. Height (cm)	Leaf area index	Above ground dry bio mass (mg ha^{-1})	AGB dry (mg ha^{-1})	Total dry biomass (mg ha^{-1})
K2O (kg ha^{-1})					
0	54.65b	4.77c	89.34c	330.06c	419.39c
100	67.44a	6.41b	186.71b	423.46b	610.17b
200	69.12a	7.09ab	232.11a	494.74a	426.86a
300	70.25a	7.48a	259.75a	515.91a	775.66a
F-test	**	**	**	**	**
LSD (5%)	4.87	0.84	33.88	68.97	93.9
CV (%)	11.07	19.44	22.72	25.34	22.93

Source: Habtam Setu et al. (2018).

Potato tuber yield

According to Geremew Taye et al. (2015), the response of potato to different rates and sources of K fertilizer is described, and the results show that different types of potassium fertilizers and rates have a substantial impact on potato tuber output.

As a result, all rates and types of fertilizer treatment in the two production years (2012 and 2013) considerably boosted potato tuber output at the Bedi, Holeta, and Gumer locations (Table 2).

During the 2012 cropping season, applications of 75 kg ha^{-1} K_2O resulted in yield advantages of 92, 100, and 117 percent over the control at the Bedi, Holeta, and Gumer sites, respectively. During the 2013 cropping season, the same treatment yielded yield advantages of 196, 161, and 186 percent over the control.

When compared to control as well as varied rates and sources of potassium fertilizer, the yield obtained by applying RR of NP and 75 kg ha^{-1} K_2O from K_2SO_4 consistently delivered the greatest significant (p0.05) potato tuber yield. However, at the Bedi, Holeta, and Gumer sites in 2012, the yield of potato tubers obtained by applying 50 kg ha^{-1} K_2O from K_2SO_4 was not significantly different from that obtained by applying 75 kg ha^{-1} K_2O from K_2SO_4.

Despite the fact that the yield produced by applying 75 kg ha^{-1} K_2O from K_2SO_4 in 2013 was much higher, it was closely followed by applying 50 kg ha^{-1} K_2O from the same source. In the years 2012 and 2013, the yield advantage was 60 to 149 percent at Bedi, 67 to 122 percent at Holeta, and 94 to 144 percent at Holeta.

Table 2. Potato tuber yield as affected by potassium fertilizers under acid soil condition at Bedi, Holeta and Gumer site.

Treatments	Bedi tuber yield (t ha^{-1})			Holeta tuber yield (t ha^{-1})			Gumer tuber yield (t ha^{-1})		
	2012 sesean	2013 sesean	Pooled over years	2012 sesean	2013 sesean	Pooled over years	2012 sesean	2013 sesean	Pooled over years
Control (no fertilizer	18.9^{c}	7.2^{f}	13.0^{f}	20.8^{f}	12.2^{c}	16.5^{f}	14.2^{d}	9.9^{c}	12.1^{f}
Recommended rate (RR) of NP	26.9^{b}	14.6^{e}	20.8^{e}	27.3^{e}	25.2^{b}	26.5^{e}	19.4^{c}	14.6^{d}	17.0^{e}
RR of NP+25 kg ha^{-1} k_2O (K_2SO_4)	30.7^{cb}	21.1^{cd}	25.9^{bcd}	33.7^{dc}	27.0^{b}	30.4^{c}	25.4^{b}	21.7^{bc}	23.5^{c}
RR of NP+50 kg ha^{-1} K_2O(K_2SO_4)	33.1^{ab}	24.7^{b}	28.9^{b}	39.6^{ba}	29.1^{ba}	34.3^{ba}	28.2^{ba}	22.7^{bc}	25.4^{bc}
RR of NP+75 kg ha^{-1} K_2O(K_2SO_4)	36.3^{a}	28.5^{a}	32.4^{a}	41.6^{a}	31.9^{a}	36.7^{a}	30.8^{a}	28.3^{a}	29.5^{a}
RR of NP+25 kg ha^{-1} K_2O(KCl)	29.0^{b}	19.1^{d}	24.1^{d}	29.7^{ed}	25.2^{b}	27.5^{de}	21.5^{c}	18.3^{dc}	19.8^{d}
RR of NP+50 kg ha^{-1} K_2O(KCl)	30.4^{ab}	20.3^{d}	25.3^{cd}	35.4^{bc}	28.2^{ba}	31.8^{bc}	25.7^{b}	21.6^{bc}	23.6^{c}
RR of NP+75 kg ha^{-1} K_2O (KCl)	31.5^{ab}	23.5^{cb}	27.5^{bc}	38.0^{bac}	28.4^{ba}	33.2^{bc}	28.5^{ba}	25.4^{ba}	26.9^{b}
LSD (0.05)	6.2	2.5	3.04	5.4	4.7	3.5	3.6	4.5	2.49
CV (%)	11.9	11	10.5	9.21	10.38	10.18	8.58	12.72	9.57

The effect of different potassium levels on the tuber yield of Irish potato at acidic soil of Chencha

In the 2007 and 2008 growing seasons, Wassie Haile et al. (2011) found that potassium administration enhanced potato tuber yields considerably compared to the control in acidic Chencha soils. Increasing the amount of K applied has resulted in an increase in tuber yield up to 150 kg ha^{-1}. The overall tuber yield grew from 15.6 tha^{-1} in the control to 57.2 tha^{-1} in 2007, with the corresponding rise in 2008 ranging from 24.5 to 50.3 tha^{-1}. In 2007, the percentage yield increases above the control ranged from 39 to 267 percent, while in 2008, it ranged from 13 to 95 percent. In 2007, the lowest percent yield increase (30%) was obtained from K level 30kha-1, while the highest percent yield increase (267%) was obtained from K level 150 kg ha^{-1}. K treatments of 30 and 150 kg ha^{-1} produced the lowest and highest yield increases over the control in 2008. respectively.

Table 3. The effect of different potassium levels on the tuber yield of Irish potato at acidic soil of Chencha.

	Tuber yield $^{ha-1}$			
Potassume levels (kg ha^{-1})	Total yield	Marketable yield	Total yield	Marketable yield
0	15.6^{d}	13.4^{d}	24.5^{c}	21.3^{d}
30	21.7^{d}	19.7^{d}	25.7^{bc}	22.8^{cd}
60	38.0^{c}	34.63^{c}	29.7^{c}	26.5^{cd}
90	40.0^{c}	36.9^{c}	35.7^{abc}	32.9^{abcd}
120	50.8^{ab}	41.8^{ab}	36.5^{abc}	34.6^{abcd}
150	57.2^{a}	55.9^{a}	50.3^{a}	49.2^{a}
210	54.8^{a}	51.8^{a}	45.2^{ab}	42.7^{ab}
240	52.3^{ab}	49.7^{a}	44.9^{abc}	42.6^{ab}
270	51.4^{ab}	48.8^{a}	33.3^{abc}	31.6^{abcd}
300	51.3^{ab}	48.5^{ab}	44.1^{abc}	41.6^{abc}
LSD (0.05)	12.3	11.7	20.3	19.2
CV (%)	16	16.7	32	32.3

Response of potato yield components to potassium fertilization

Potato yield components such as number of tubers per square meter and average tuber weight were measured in both seasons for all sites, according to Geremew Taye et al. (2015). Similar response tendencies to treatment effects were observed in both seasons. At all locations, significant disparities in average tuber weight were also detected. The application of 75 kg ha^{-1} K_2O in combination with the prescribed amount of NP-Fertilizer resulted in the highest tuber weights. At the Bedi, Holeta, and Gumer sites, this treatment produced a weight advantage of 9.7 g (17%), 27.6 g (45%), and 18.5 g (39%), respectively, over the recommended rate of NP fertilizer (Table 4). This is related to the fact that applying K fertilizer to potatoes increases the tuber size. K_2O applied as potassium sulfate had a larger tuber weight advantage than potassium chloride applied at equal rates, corresponding to tuber yields.

Table 4. Potato yield components as affected by potassium fertilizers pooled over years at Bedi, Holeta and Gumer sites.

	Average tuber weight (G)			Tuber number m		
Treatment	Bedi	Holeta	Gumer	Bedi	Holeta	Gumer
Control (no fertilizer	54.3	61.7^{c}	38.1^{d}	25^{d}	25^{d}	32^{e}
Recommended rate (RR) of NP	58.3	60.7^{c}	47.5^{c}	38^{c}	39^{c}	37^{d}
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	57.8	75.5^{b}	56.8^{b}	47^{ba}	42^{bc}	42^{ba}
RR of NP+50 kg ha^{-1} K_2O (K_2SO_4)	62	76.3^{b}	61.3^{ba}	48^{a}	45^{cba}	43^{ba}
RR of NP+75 kg ha^{-1} K_2O (K_2SO_4)	68	88.3^{a}	66.0^{a}	50^{a}	48^{a}	46^{a}
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	59.7	62.3^{c}	55.1^{bc}	42^{bc}	43^{cba}	37^{dc}
RR of NP+50 kg ha^{-1} K_2O (K_2OSO_4)	59.3	71.0^{bc}	62.1^{ba}	44^{ba}	$46b^{a}$	39^{dcb}
RR of NP 75 kg ha^{-1} K_2O (K_2OSO_4)	60.8	78.3^{ba}	67.0^{ba}	46.2^{ba}	$48b^{a}$	42^{cba}
LSD (0.05)	12.24	10.8	8.1	5.6	6.64	4.34
CV (%)	17.42	12.88	12.21	11.44	13.57	9.36

With the application of K fertilizer, the number of tubers per square meter increased, and significant changes in tuber number were detected at all locations. When 50 and 75 kg K_2O ha^{-1} were treated in both kinds of K fertilizer, the number of tubers produced per square meter was higher than the required rate of NP fertilizer (Table 4).

Changes in soil chemical properties

The pH and exchangeable acidity (EA) (meq/100g soil) of Holeta 5.3 and 0.11, Bedi 4.62 and 2.14, and Gumer 4.5 and 2.7, respectively, were determined by soil analysis prior to planting. According to the pH values listed above, the soil was strongly acidic in Holeta and extremely acidic at Bedi and Gumer. Table 4, 5, and 6 illustrate changes in soil chemical characteristics as a result of K fertilizer application in three test sites. The pH of the soil was found to be acidic at all locations, with low organic carbon (OC) concentration and total nitrogen at Holeta and medium at Bedi and Gumer (Table 5). At all locations, available P (Bray II technique) is low, while CEC is medium.

Table 5. Effect of potassium application on some soil chemical properties at Bedi.

Treatment	F36	OC (%)	P(ppm)	CEC (cmol kg^{-1})	Total N (%)	K (cmol kg^{-1})
Control (no fertilizer)	4.28	2.41	8.27	17.73	0.23	0.41^{c}
Recommended rate (RR) of NP	4.29	2.41	8.57	17.79	0.24	0.45^{bc}
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	4.32	2.43	9.11	18.39	0.24	0.48^{bc}
RR of NP+50 kg ha^{-1} K_2O (K_2SO_4)	4.32	2.45	9.21	18.72	0.23	0.53^{bc}
RR of NP+75 kg ha^{-1} K_2O (K_2SO_4)	4.39	2.45	9.98	19.6	0.23	0.58^{a}
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	4.31	2.4	8.63	18.55	0.23	0.48^{bc}
RR of NP+50 kg ha^{-1} K_2O (K_2OSO_4)	4.32	2.44	9.39	18.9	0.23	0.48^{bc}
RR of NP 75 kg ha^{-1} K_2O (K_2OSO_4)	4.38	2.45	9.43	19.02	0.24	0.51^{ab}
LSD (0.05)	NS	NS	NS	NS	NS	0.09
CV (%)	2.58	4.47	13.76	4.88	6.54	11.06

At Bedi and Gumer, exchangeable K is medium, but at Holeta, it is high. Except for exchangeable K at the Bedi and Holeta locations, neither source of potassium fertilizer had a substantial impact on any of the criteria (Table 5). Potassium fertilizer treatments, on the other hand, significantly enhanced the exchangeable K content of the soil at Holeta and Bedi, where changes in K were linearly proportional to increases in K rates for both fertilizer sources at Bedi and Holeta (Tables 5 and 6).

Table 6. Effect of Potassium application on some soil chemical properties at Holeta.

Treatment	pH	OC (%)	P(ppm)	CEC (cmol kg^{-1})	Total N (%)	K (cmol kg^{-1})
Control (no fertilizer)	4.76	1.83	7.08	18.56	0.16	0.86^{c}
Recommended rate (RR) of NP	4.79	1.86	7.12	19.66	0.17	0.93^{c}
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	4.9	1.87	8.11	19.74	0.17	1.04^{b}
RR of NP+50 kg ha^{-1} K_2O (K_2SO_4)	5.35	1.87	9.06	20.42	0.17	1.12^{ab}
RR of NP+75 kg ha^{-1} K_2O (K_2SO_4)	5.56	1.99	9.18	22.27	0.17	1.14^{a}

RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	5.01	1.84	7.34	19.81	0.17	1.03^{b}
RR of NP+50 kg ha^{-1} K_2O (K_2OSO_4)	5.17	1.91	7.87	20.4	0.18	1.09^{ab}
RR of NP 75 kg ha^{-1} K_2O (K_2OSO_4)	5.28	1.98	8.1	20.4	0.17	1.16^{a}
LSD (0.05)	NS	NS	NS	NS	NS	0.09
CV (%)	13.53	4.77	11.61	13.25	4.66	5.22

The highest K rates applied in the forms of potassium sulfate and potassium chloride elevated K levels by 0.18 (43%) and 0.11 (26%) over the control, respectively, at Bedi (Table 5). The variations in K found at Holeta, on the other hand, were enormous. In comparison to the control, 75 kg of K_2O ha^{-1} in the forms of potassium sulfate and potassium chloride elevated K value by 0.28 (33%) and 0.3 (35%) respectively. The changes in pH, available P, and CEC explained by changes in K sources and rates, on the other hand, were minor and inconsequential (Tables 5-7).

Table 7. Effect of Potassium application on some soil chemical properties at Gumer.

Treatment	pH	OC (%)	P (ppm)	CEC (cmol kg^{-1})	Total N (%)	K (cmol kg^{-1})
Control (no fertilizer)	4.31	5.24	4.32	24.09	0.43	0.22
Recommended rate (RR) of NP	4.35	5.83	4.42	25.54	0.45	0.22
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	4.42	6	5.09	25.55	0.44	0.23
RR of NP+50 kg ha^{-1} K_2O (K_2SO_4)	4.43	6.01	5.12	26.16	0.44	0.24
RR of NP+75 kg ha^{-1} K_2o (K_2SO_4)	4.45	6.07	5.26	26.23	0.45	0.25
RR of NP+25 kg ha^{-1} K_2O (K_2SO_4)	4.41	5.72	4.89	25.38	0.44	0.21
RR of NP+50 kg ha^{-1} K_2O (K_2OSO_4)	4.42	5.88	4.94	25.61	0.44	0.22
RR of NP 75 kg ha^{-1} K_2O (K_2OSO_4)	4.45	5.89	5.27	26.09	0.45	0.26
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	2.04	6.88	12.71	4.2	2.92	12.76

Source: Geremew Taye et al. (2015).

Conclusion

There is clear evidence of the need for K fertilizers in the form of K_2SO_4 or KCl to be applied to potatoes. Potatoes, on the other hand, responded more strongly to K fertilizer than to K_2SO_4. The findings contradict the idea that Ethiopian highland soils are formed from K-rich parent material and that K fertilizers are unnecessary. After a lengthy period of intensive cropping and increased nitrogen fertilizer use, the availability of K in the soil may have reduced. According to the current scenario, potassium response is observed in Ethiopia's highlands, particularly in acid soils where nitisol predominates. This could be due to substantial nutrient depletion due to erosion and leaching.

As a consequence, for long-term and higher productivity, potato production in Ethiopia's highlands should include the use of K fertilizer in the form of K_2SO_4.

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