Research Findings

Research team evaluating the field experiment. Photo by Bao Pham Vu.

Effect of Potassium Fertilizer Types and Rates on Peanut Growth and Productivity on Coastal Sandy Soil in South Central Vietnam

Truong Thi Thuan[(1)], Duong Minh Manh[(1)], Pham Vu Bao[(1)*], Ho Huy Cuong[(1)], Hoang Minh Tam[(1)*], and Tran Quoc Dat[(1)]

Abstract

Two potassium fertilizer types (potassium chloride {KCl} and potassium sulfate {K_2SO_4}), at five distinct doses (0, 30, 60, 90, and 120 kg K_2O ha^{-1}) were applied to determine a suitable potassium (K) fertilization approach for a new peanut cultivar, LDH.09, especially selected for peanut cultivation on the saline coastal sandy soils of Binh Dinh province, Vietnam. While neither fertilizer significantly influenced peanut growth and yield parameters under the majority of doses, the effect of dose on yield was dramatic, particularly at low doses (30 and 60 kg K_2O ha^{-1}), illustrating a saturation curve. The economic optimum was already reached at a dose of 30 kg K_2O ha^{-1}. Excluding a significant rise in soil pH due to liming, soil fertility remained very low at the end of the trial, indicating an unsustainable crop system. These results suggest that most of the applied K was wasted before reaching the plants' roots. Therefore, alternative approaches to fertilization for highly productive and sustainable

[(1)]Agricultural Science Institute for Southern Centre of Vietnam (ASISOV)
*Corresponding author: vubaokhktnn@yahoo.com

peanut crop systems in Binh Dinh, should be considered. This could include splitting the K dose into many frequent applications, and/or employing fertilizers which exhibit slow-release nutrient properties.

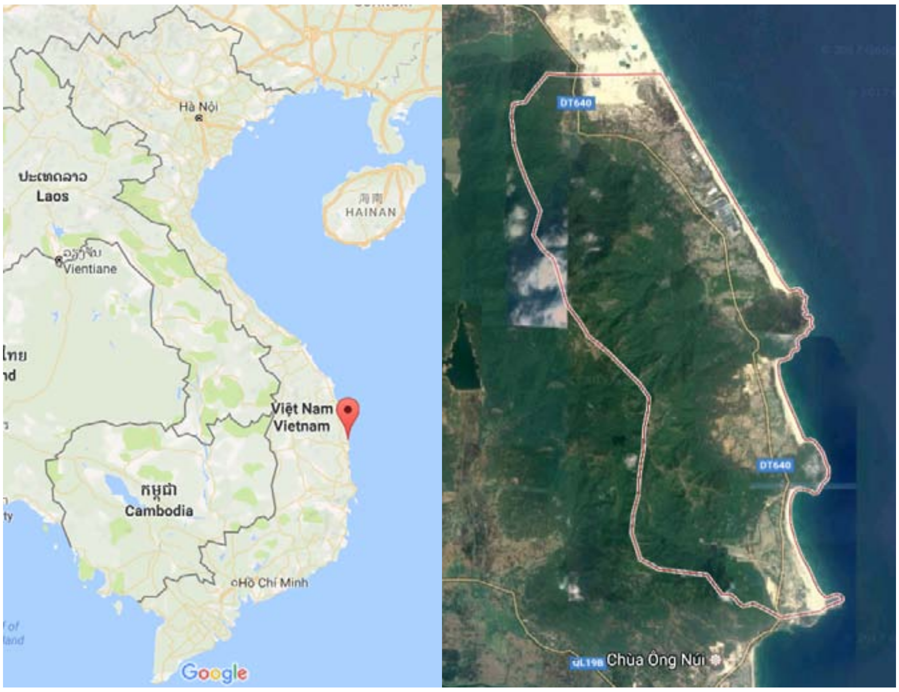
Keywords: Acid soil; *Arachis hypogaea* L.; potassium; saline; sand.

Introduction

Peanut (*Arachis hypogaea* L.) is a short-term industrial oil crop with high nutritional and economic values. In Vietnam, this crop is aimed at replacing less profitable and unsustainable crops and has recently gained priority in many provinces, including Binh Dinh (Map 1). The land area in Binh Dinh used to cultivate peanut has increased from 7,700 ha in 2005 to 10,200 ha in 2013. Peanut is mainly grown on the saline coastal soils of Binh Dinh due to competition from alternative crops on alluvial and poor gray soils. This area of peanut cropping is generally characterized by poor soil fertility, high salinity, frequent droughts and water shortage (Keen *et al.*, 2013). Nevertheless, these challenges have promoted research efforts to define the factors limiting peanut culture in the area; to select suitable cultivars; and to examine innovative farming techniques.

In the frame of these efforts, the Agricultural Science Institute of Southern Central Coastal region of Vietnam has recently selected a new peanut cultivar LDH.09, a H1 hybrid combination of ICG20 x 9205. Under moderate saline conditions, LDH.09 consistently displays 32 and 51% higher productivity than the control L14 and the local Se cultivars, respectively (Cuong *et al.*, unpublished data).

However, the poor soil fertility - particularly the low potassium (K) status - and the most effective approach to supply peanut K requirements under the local conditions, are of great concern. Several studies ended with disparate results regarding the most productive and economically efficient K dose that should be applied to peanuts on the saline sandy soils in Binh Dinh. From various studies, the recommended K dose for optimum growth is 60 kg K_2O ha^{-1} (Dan, 1995; Bo *et al.*, 1999; Chinh, 2005). This is supported by Chinh *et al.* (2012) and Hoa *et al.* (2012), who concluded in separate studies that 60 kg K_2O ha^{-1} is the optimum K dose for peanut crops on the sandy soils in Thanh Hoa and Binh Dinh. However, several more recent experiments yielded widely ranging optimum K values from 8 to 76 kg K_2O ha^{-1}. Tam *et al.* (2014, unpublished data), and Minh (2014) found that a higher K dose of 80 kg ha^{-1} was the most productive and economically efficient measure on sandy soil in Quang Binh. Hung (2011) suggested an even higher optimum dose of between 90 and 120 kg K_2O ha^{-1} for the saline sandy soils of Thai Binh and Thanh Hoa.



Map 1. Cat Hai, Phu Cat district, Binh Dinh Province, Vietnam. *Source:* Google Maps, 2017.

These contradictory results, and the need to establish solid fertilizer recommendations for the new peanut cultivar LDH.09, have set the objective of the present study - to determine the appropriate K fertilizer type and dose for peanut grown on the saline coastal sandy soils in Binh Dinh.

Materials and methods

The experiment was carried out on the coastal saline soil at the Cat Hai Commune, Phu Cat district, Binh Dinh province. Prior to the trial the soil was acidic (pH_{KCl} 4.85), with low organic material (humus content - 0.56%), poor total nitrogen (N) content (0.09%), high phosphorus (P) (0.05%), low K (0.07%), and moderate to high chlorine (Cl) (0.07%).

Basal fertilizer application comprised of 5 Mg manure, 15 kg N (urea), 90 kg P_2O_5 (superphosphate), and 250 kg powdered limestone, per hectare. The first top dressing took place at the emergence of 2-3 true leaves with an application of 15 kg N (urea), and the second one, carried out at full bloom, consisted of an additional 250 kg ha^{-1} of limestone.

The field was ploughed and 1.2 m wide and 0.15 m high seedbeds were prepared, separated at a distance of 0.3 m. Seeds were sown in four rows per seedbed, at 30 and 10 cm, apart and within a row, respectively (33.3 plants m^{-2}).

Treatments included two types of K fertilizer - potassium chloride (KCl) and potassium sulfate (K_2SO_4), and each was tested at five doses split evenly between two applications: basal, and the first side dressing at the emergence of 2-3 true leaves (Table 1). The experiment was designed in split-plot layout with three replications of 12 m^2 each.

Water was supplied to maintain soil moisture above 65%. Pests and diseases were managed according to their occurrence at threshold levels, implementing common recommendations. Harvest took place when 80-85% of fruit had reached maturity. Fruit were collected separately from each plot and dried to a 10% grain moisture level.

Crop development (plant height, plant survival, time of full bloom) was recorded for each plot from germination to harvest. Evaluations of pests and major diseases were carried out throughout the season. At harvest, 10 plants per plot were sampled to determine fresh and dry plant biomass and yield determinants such as the number of filled pods per plant, the weight of 100 pods, and the weight of 100 dry (10% moisture content) seeds, as well as the total dry grain yield. The economic assessment was founded on the calculation of costs (as influenced by the two fertilizers), revenue (dry grain yield, quality, and price), net profit to the farmer, and the benefit rate (profit and cost ratio). Soil examinations were carried out on each plot before sowing and after harvest to measure pH_{KCl}, and total quantity (%) and availability (mg 100 g^{-1}) of N, P_2O_5 and K_2O.

The experiment was repeated three times: spring to summer 2015, summer to fall 2015, and spring to summer 2016. Data analysis was carried out using Statistix 8.2.

Results

Fertilizer type and dose did not have any significant influence on the LDH.09 peanut cultivar regarding the time required for plant growth, which ranged from 90 to 92 days for all three crops. The levels of leaf spot (*Cercospora personatum* {Berk. & Curt.}), leaf rust (*Puccinia arachidis* Speg.), bacteria wilt (*Ralstonia solanacearum* Smith.), and root rot (*Aspergilus niger*) remained very low to low for all crops and throughout all treatments. No effects were observed either for plant disease resistance, excluding L_1K_0 which occasionally displayed slightly higher susceptibility to the leaf spot and the leaf rust diseases.

Fertilizer types KCl and K_2SO_4 had minor effects on plant height, which was higher under KCl but had no significant influence on other plant development and yield determining parameters. The harvested yield was slightly, but insignificantly higher under KCl treatments (Table 2).

In contrast, K dose had significant effects on most parameters of plant growth, yield, and consequently, grain yield (Fig. 1). No effects were observed regarding the number of plants reaching harvest, branching rate, and the seed to fruit ratio. For all parameters influenced, saturation curves were found to best depict the K dose effect. The lowest K dose of 30 kg K_2O ha^{-1} had the most significant effect, boosting plant height and pod number, whereas the effect of higher K doses were insignificant or relatively minor (Fig. 1AB). A K dose of 60 kg ha^{-1} appears to bring about a consequent rise in pod or seed weight (Fig. 1C), which was possibly projected on the final grain yield (Fig. 1D). However, the higher K doses of 90-120 kg ha^{-1}, did not give rise to any advantage for peanut crop growth in the present study. The interaction between fertilizer type and dose was statistically insignificant for all measured parameters.

Table 1. Description of K fertilization treatments employed in the peanut experiment held at Cat Hai, Binh Dinh Province, Vietnam.

Fertilizer type	Treatment	Basal	At 2-3 true leaves	Total
		K dose (kg K_2O ha^{-1})		
KCl	L_1K_0 (control)	0	0	0
	L_1K_1	15	15	30
	L_1K_2	30	30	60
	L_1K_3	45	45	90
	L_1K_4	60	60	120
K_2SO_4	L_2K_0 (control)	0	0	0
	L_2K_1	15	15	30
	L_2K_2	30	30	60
	L_2K_3	45	45	90
	L_2K_4	60	60	120

Table 2. Effect of K fertilizer type on the growth and yield of peanut (cv. LDH.09) grown on the coastal saline sandy soil in Binh Dinh, Vietnam. Values are means of three cropping seasons in 2015 and 2016. Different letters indicate significant statistical differences at p = 0.05.

Treatment	Harvested plants	Plant height	Number of primary branches	Number of pods	Weight of 100 pods	Seed to fruit ratio	Harvested yield
	Plant m^{-2}	*cm*	*Plant^{-1}*		*g*	*%*	*Mg ha^{-1}*
L_1 (KCl)	28.3	26.1[a]	4.9	12.6	166.1	65.3	3.18
L_2 (K_2SO_4)	28.6	23.7[b]	4.9	12.8	167.3	65.1	3.08
P type	*0.1266*	*0.0119*	*0.0632*	*0.2784*	*0.0819*	*0.6887*	*0.0586*

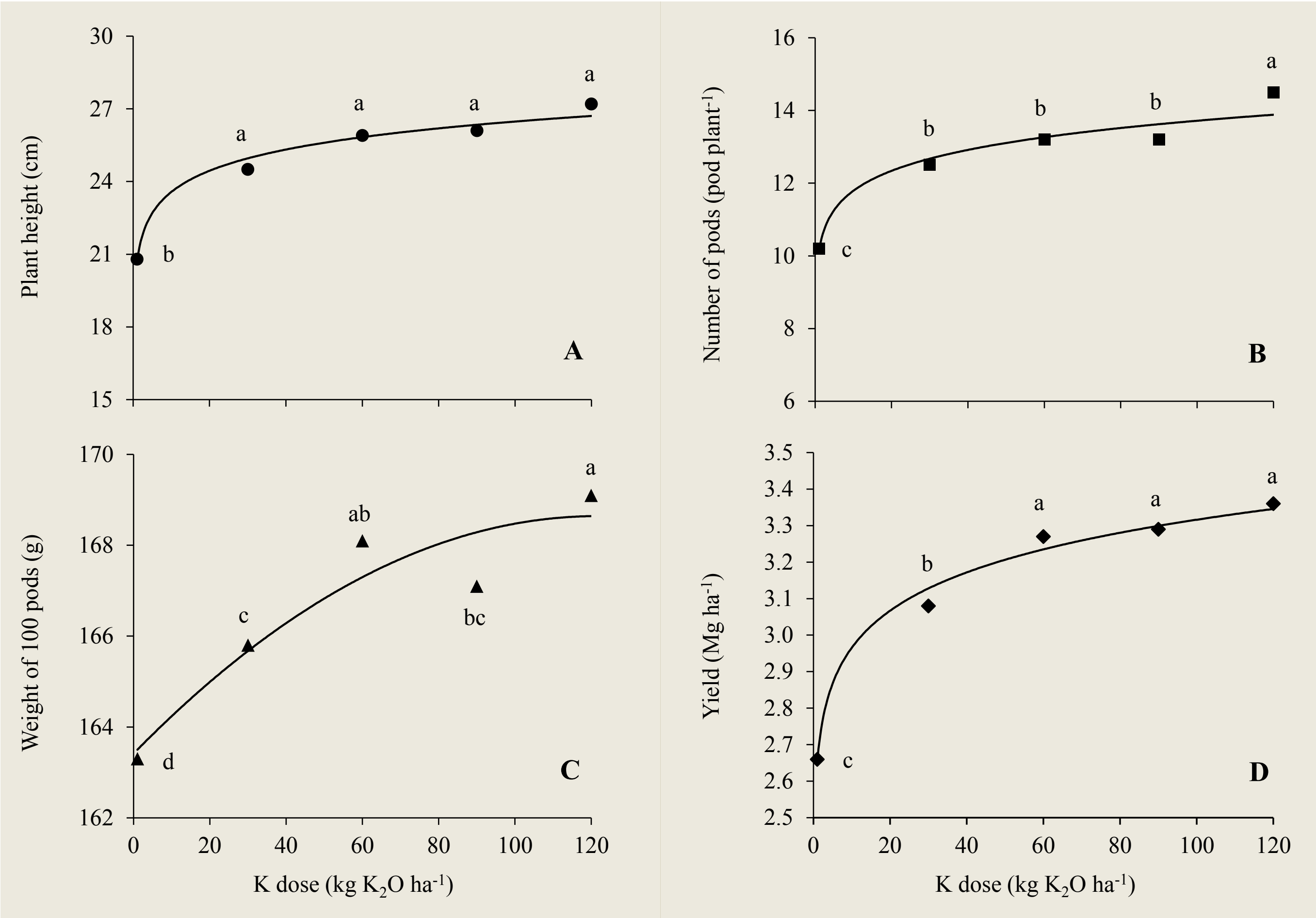


Fig. 1. Effect of K dose on the growth and yield of peanut (cv. LDH.09) grown on coastal saline sandy soil in Binh Dinh, Vietnam. Values are means of three cropping seasons in 2015 and 2016. Different letters indicate a significant statistical difference at $p = 0.05$.

As the K_2SO_4 fertilizer was more expensive than KCl, the cost of peanut production under this treatment linearly increased with K dose, which gradually opened significant gaps in the total cost between crops fertilized with KCl and K_2SO_4 (Fig. 2A). The profit obtained from KCl-applied crops upsurged dramatically in response to the lowest K dose of 30 kg ha^{-1}, but any further increase in profit was insignificant. The increase in net profit was much slower for the K_2SO_4-applied crops, peaking with a dose of 60 kg K_2O ha^{-1} but then declining steeply with increased K doses (Fig. 2B). A similar trend was observed for the profit to cost ratio (Fig. 2C).

The soil analyses results for before and after the trials are shown in Table 3. Interestingly, soil pH_{KCl} increased considerably from an acidic 4.85 before the trails, to a neutral range of 6-7. Total N content, which was low before the trails at 0.09%, significantly declined further under the KCl treatments and fluctuated incosistently under K_2SO_4. Soil available N fluctuated between 2.98 and 4.48 mg 100 g^{-1} with no obvious relation to fertilizer type

Peanut growth performance field experiment. Photo by Bao Pham Vu.

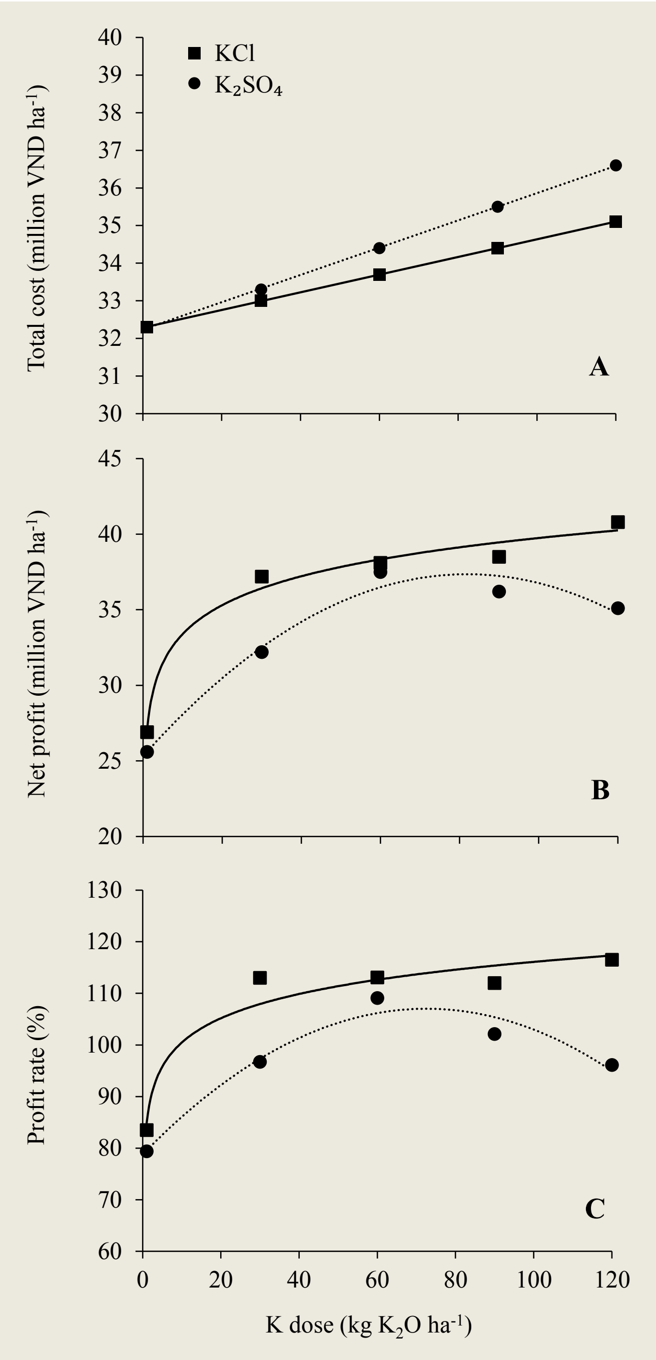


Fig. 2. Effects of K fertilizer type and dose on the total cost (A), net profit (B), and profit to cost ratio (C) for peanut crops grown on saline coastal sandy soil in Binh Dinh, Vietnam.

or dose. Total P levels were high before the trials and increased towards the end of the trials. The levels of available P after trials ranged between medium to very high. Total soil K, which was very poor before the trials (0.07%), slightly increased or remained at the same range. Available K remained at poor to very poor levels, ranging from 2.05 to 5.06 mg 100 g^{-1} irrespective of fertilizer type and dose, and yield levels. The soil salinity level, as indicated by the chloride concentrations, slightly decreased during the trial.

Discussion

A sustainable agricultural system largely depends consistent soil fertility. In cases of poor initial soil fertility, as with saline sandy soils, steps should be taken to steadily improve it. The increase in soil pH observed during trials is a positive sign, although reassessment is required to verify the stability of this trend. For peanut, the recommended pH range is betweem 5.8 and 6.2. If pH is less than 5.8, zinc toxicity problems can occur (Balota, 2014).

Nevertheless, the prevailing poor N status of the soil (Table 3) is a concern as this will restrict any crop, regardless of which and to what extent other fertilizers are supplied. Peanut gets most of its N from nitrogen-fixing bacteria (Bradyrhizobium) colonizing the plant's roots. Poorly inoculated fields will not usually show any yellowing until the beginning of flowering, so checking for nodulation before flowering is important. Failure of natural inoculation can be expected in very humid soils, in such cases, N fertilizer should be applied carefully to reach a sufficient range of 3.5-4.5% in leaves at bloom or early pegging (Balota, 2014). Urea application to acidic soils might further decrease soil pH (Bouman *et al.*, 1995; Tong and Xu, 2012), inhibit soil microflora (Geisseler and Scow, 2014), and weaken N_2-fixation by legume crops (Miller, 2016). Therefore, the replacement of urea with other N-donating fertilizers should be considered.

Evaluations of K supply efficiency to peanut crops provide three important comprehensions: 1) crop and yield responses were largely limited to the lowest K doses applied i.e. 30 and 60 kg ha^{-1}. Under higher dosage, even at 120 kg ha^{-1}, any further yield increase was negligible (Fig. 1); 2) soil K status did not change significantly, remaining very poor at harvest, irrespective of K dose (Table 3); 3) the two K fertilizers, KCl and K_2SO_4, did not differ in their influence on crop growth and soil fertility. This result is not surprising for sandy, acid soils (De Geus, 1973). Soil particles with low specific surface area (sand), combined with high proton concentrations in the liquid soil phase (high acidity), substantially repress soil cation exchange capacity. Thus, the chances for free-K^+ ions - applied through fertilizers - to be transiently adsorbed by the soil particles and establish higher K availability, are extremely low. Instead, the K^+ ions are flushed away by frequent rains before they can be taken up by the crop hence, only a small fraction reaches the plants regardless of fertilizer dose, and the rest is wasted.

There are two approaches to overcome this problem - the first is to split the K dose into many frequent applications, thus increasing the chances for K uptake. Where supplemental irrigation

Table 3. Effect of K fertilizer type and dose on soil chemical properties.

Fertilizer type	Treatments	pH_{KCl}	Total N	Total P_2O_5	Total K_2O	Available N	Available P_2O_5	Available K_2O	Cl^-
	K_2O (kg ha^{-1})		-------------%------------			--------*mg 100 g^{-1}*-------			%
		Before trials							
		4.85	0.09	0.05	0.07	-	-	-	0.07
		After trials							
KCl	0	6.6	0.06	0.08	0.10	4.48	25.07	3.37	0.05
	30	6.3	0.06	0.06	0.09	4.27	12.53	2.41	0.05
	60	6.5	0.06	0.07	0.08	3.40	14.62	2.05	0.04
	90	6.7	0.05	0.05	0.09	3.78	22.34	4.10	0.04
	120	7.1	0.06	0.06	0.09	3.12	25.55	5.06	0.04
K_2SO_4	0	7.0	0.09	0.08	0.06	3.64	20.09	2.41	0.04
	30	6.3	0.05	0.05	0.08	3.68	15.43	2.89	0.05
	60	6.9	0.10	0.13	0.07	3.29	23.46	4.46	0.04
	90	6.8	0.12	0.14	0.06	2.98	18.48	4.46	0.06
	120	7.1	0.09	0.05	0.08	3.92	18.48	4.58	0.04

is employed, K should be applied simultaneously with the water, preferably toward the end of the irrigation event. The second approach is to employ relatively slow-release fertilizers, as suggested by Keen *et al.* (2013). A good example of this approach can be found in a recently published study by Tam *et al.* (2016), where polyhalite was tested against KCl in peanut and significantly increased soil K availability after harvest.

Figure 2 demonstrates the economic benefit of using one fertilizer over another; although in general, no significant differences occurred between the two fertilizers in regards to yield (Fig. 1D), there was a slight, insignificant advantage under the KCl treatment at a dose of 30 kg ha^{-1} (3.19 vs. 2.98 Mg ha^{-1} under KCl and K_2SO_4, respectively). This, together with the higher cost of the K_2SO_4 fertilizer, determined that economically, the most efficient treatment was KCl at a dose of 30 kg ha^{-1} (Fig. 2B). However, the modified fertilization approaches mentioned above might bring about significantly higher yields with higher fertilizer requirements, but under more sustainable conditions. As such, a reassessment of the economic calculations would be required.

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References

Balota, M. 2014. Peanut (*Arachis hypogaea* L.). Nutrition. https://vtechworks.lib.vt.edu/handle/10919/56116.

Bo, N.V., E. Mutert, and N.T. Thi. 1999. Some Research Results on Balance Fertilizer for Plants in Vietnam. Scientific research results of Soils and Fertilizers Institute 3:307-335.

Bouman, O.T., D. Curtin, C.A. Campbell, V.O. Biederbeck, and H. Ukrainetz. 1995. Soil Acidification from Long-Term Use of Anhydrous Ammonia and Urea. Soil Science Society of America Journal 59:1488-1494.

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Arachis hypogaea flower. Photo by Cuong Ho Huy.

Chinh, N.T. 2005. The Intensive Farming Technology for High-Yield Peanut. Agricultural Publishing House, Hanoi.

Chinh, V.D., and T.T. Nien. 2012. The Effects of the Dosage of Fertilizer on the Growth, Development and Yield of some Peanut Varieties in Autumn-Winter Crop Condition in Hoang Hoa - Thanh Hoa. Journal Learning and Development 10:821-829.

Cuong. H.H., N.V. Thang, and H.V. Tam. 2016. Breeding of Salt-Tolerant Peanut Variety LDH.09 for Southern Central Coastal Areas. Journal of Vietnamese Agricultural Science and Technology 8(69):15-22.

Dan, N.T. 1995. The Usage of Appropriate Fertilizer for Peanut in Autumn on Infertile Soils in Ha Bac. Scientific research results legume crops from 1991 to 1995. The Institute of Agricultural Science and Technology, Vietnam 6:114-118.

De Geus, J.G. 1973. Fertilizer Guide for Tropicals and Subtropicals. 2nd edition, Centre d'Etude de I' Azote Zurich. p. 440-471.

Geisseler, D., and K.M. Scow. 2014. Long-Term Effects of Mineral Fertilizers on Soil Microorganisms - A Review. Soil Biology and Biochemistry 75:54-63.

Hoa, H.T.T., and L.H. Lam. 2012. Research on the Effects of Nitrogen and Potassium Fertilizer Rates on Peanut Yield in Coastal Sandy Soil in Binh Dinh Province. Journal of Science, University of Hue, Episode 71(2):133-144.

Hung, P.D. 2011. Impact of Injected Salty Soils on Some Main Crops' Yield, Quality (Rice, Peanut, Sweet Potato Crops) and Recommendations in the Red Delta and Northern Center Zone of Vietnam. Final project report by the Agricultural Planning Institute.

Keen, B., C.T. Hoanh, P. Slavich, R. Bell, and H.M. Tam. 2013. Opportunities to Improve the Sustainable Utilisation and Management of Water and Soil Resources for Coastal Agriculture in Vietnam and Australia. A report published by ACIAR, GPO Box 1571, Canberra ACT 2601, Australia.

Miller, J.O. 2016. FS 1054: Soil PH and Nutrient Availability. http://drum.lib.umd.edu/handle/1903/18519.

Minh, H.K. 2014. The Study of Technical Measures to Increase Productivity and Production Efficiency in Peanut (*Arachis hypogaea* L.) on Sandy Soil Quang Binh, Ph.D dissertation Agricultural Sciences. Ministry of Agriculture and Rural Development (2014), database, http://www.agroviet.gov.vn.

Tam, H.M., D.M. Manh, T.T. Thuan, H.H. Cuong, P.V. Bao. 2016. Agronomic Efficiency of Polyhalite Application on Peanut Yield and Quality in Vietnam. IPI *e-ifc* 47:3-11.

Tong, D., and R. Xu. 2012. Effects of Urea and $(NH_4)_2SO_4$ on Nitrification and Acidification of Ultisols from Southern China. Journal of Environmental Sciences 24:682-689.

The paper "Effect of Potassium Fertilizer Types and Rates on Peanut Growth and Productivity on Coastal Sandy Soil in South Central Vietnam" also appears on the IPI website at:

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