INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 5, p. 207-216, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

The evaluation effects of potassium and magnesium on yield and some physiological traits of Soybean (*Glycine max* L.) based on some statistical analysis

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Article published on May 29, 2017

Key words: Soybean, Potassium, Magnesium, Seed yield

Abstract

In order to investigate the effects of potassium and magnesium on yield parameters of soybean, present study was conducted at research farm of Daronkola located at Babol during 2012-2013 growing season which used factorial arrangement based on completely randomized block design with three blocks. The treatments consisted of potassium phosphate and magnesium sulfate application that potassium phosphate at three levels (0, 100, 200kgr/hectare) and magnesium sulfate at two levels (0 and 100 kgr/hectare). Results showed that Potassium and magnesium treatments and its interaction were effective significantly on plant height and Reproductive period length in one percent level. These treatments improved crop yield and yield components. With adding potassium and magnesium fertilizers to soil, plant height, Reproductive period length and Seed yield increased. Seed per pod was more effective factor than other yield components on seed yield.

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Introduction

Soybean [*Glycine max* (L.) Merrill] is the world's leading source of oil and protein. It has the highest protein content of all crops and is second only to groundnut in terms of oil content among legumes (Gurmu *et al.*, 2009). Many soybean products are directly used for human consumption such as soymilk, soya sauce, protein extracts and concentrates. Apart from nutritional qualities, soybean yield is higher than other common food legumes, relatively has few field and storage pests and diseases and has a high nitrogen fixing ability (Vanlauwe *et al.*, 2011). Low soybean yields are largely attributed to lessen of soil fertility (Thuita *et al.*, 2012). However, in most cases, breeders look for a variety that has good mean performance over a wide range of environments and years and the concept of stability is overlooked.

Magnesium (Mg) is an important macronutrient with a number of physiological functions in the plant. The importance of magnesium in the plant is in many ways connected with photosynthesis. It is the central atom of chlorophyll and it activates enzymatic processes. Magnesium also favorably influences assimilation (Mengel and Kirkby, 2001). Magnesium deficiency reduces the content of chlorophyll in the leaves and changes the chlorophyll *a*: *b* ratio in favor of chlorophyll *b*. Visually it is seen as chlorosis of leaves, especially older ones and causes premature abscission. Chlorosis is caused either by Mg deficiency, high content of soil Ca (calcareous soils) or a combination of these factors (Marschner, 2002; Ksouri *et al.*, 2005; Gluhić *et al.*, 2009). Magnesium uptake by the plant is also affected by the antagonistic effect of Ca and K and as was confirmed by Garcia *et al.* (1999).

Potassium (K) is an essential element for plant nutrition and its ability to influence meristem growth, water status, photosynthesis and long distance transport of assimilates is well established (Mengel and Kirkby, 2001). Potassium is a macro nutrient which is accounted as a necessary and more effective nutrient in plant root and crop yield (Jalali, 2010). Owing to its fundamental roles in turgor generation, primary metabolism, and long-distance transport, K plays a prominent role in crop resistance to drought, salinity, high light, or cold as well as resistance to pest and pathogens. In K-deficient crops, the supply of sink organs with photosynthetic is impaired and sugars accumulate in source leaves. This not only affects yield formation, but also quality parameters, for example in grape (Zörb *et al.*, 2014). Response surface methodology (RSM) represents a collection of statistical and mathematical techniques and it is often used for development, improvement and optimization of various processes, where certain response is influenced by several variables (Bas & Boyacı, 2007; Bezerra, Santelli, Oliveira, Villar & Escaleira, 2008).

Hosseini *et al* (2016) and Amini and Movahedi Naeini, 2013 reported that increasing potassium uptake caused improve crop yield and component yield. A key question is whether present potassium management recommendations are enough to meet future needs. Fertilizer recommendation algorithms must be more robust and adjust different crops, cropping systems, crop management technologies, soil conditions, and climate-driven yield potential (Dobermann, 2001). The goal of the present study was to evaluate the effects of potassium and magnesium on yield and some physiological traits of Soybean. Furthermore, this paper focuses on relationship between seed yield and yield component.

Materials and methods

Study area and Experimental setup

This research was carried out in Daronkola located at Babol, Iran during 2012-2013 growing season. Which used factorial arrangement based on completely randomized block design with three blocks. Each experimental plot had 5 meters long and 3 meters (3m×5m) wide and 6 ridges spaced 50 cm apart. Soil samples were collected and its physicochemical properties were analyzed in soil science laboratory, Department of soil science, Sari Agricultural sciences and natural Resources University.

Uniform healthy soybean seeds were purchased from Iran's Oilseed Research and Development Company Deputy of Sari, Iran. Seeds were used for hand sowing in the month of June, 2012 after removing the trashes and impurities.

Treatment

The treatments consisted of potassium phosphate and magnesium sulfate application that potassium phosphate at three levels (0, 100, 200kgr/hectare) and magnesium sulfate at two levels (0 and 100 kgr/hectare).

Soil physical and chemical Measurements

A composite soil sample was obtained from 0-40 cm depth from each site for physical and chemical determination. The soil textural class was clay silty as measured by the hydrometer method (Klute and Dinauer, 1986). Other measurements were soil organic carbone content (Chapman, 1965), pH, EC, total nitrogen, phosphorus, potassium and Zn-DTPA (Pag, 1982). At physiological maturity, net plots were harvested for assessment (0.9 m-2). Data were collected on the seed yield (kg/ha), seed weight (1000 seed weight in grams), number of pods per plant, Node number, Number of lateral stem, Reproductive period length, Pod number, Pod dry weight, Seed per pod and plant height. At maturity, plants of 4.4 m^2 in the middle part of each plot were harvested and grain yield per unit area was determined.

Statistical analysis

Data analysis include the analysis of variance, mean comparisons, Principal component analysis and correlations which carried out using SPSS software.

Results of soil analysis before planting

The basic information of soil properties firstly obtained: Total nitrogen (0.275 %), available phosphorus (11.1 mg Kg^{-1} soil) and potassium (257.3 mg Kg^{-1}) and pH, EC and OC were 7.2, 1.2 ds m^{-1} and 1.35%, respectively. Soil texture was clay silt (table 1). Results showed that concentration of the Potassium uptake were very high (lower 40, 41-80, 81-120, 121-160 and higher 160 mgr per kgr soil Potassium uptake of soil is showed very low, low, medium, high and very high respectively), available phosphorus in very high (lower 3, 4-7, 8-11, 11-20 and higher 20 mgr per kgr soil are showed very low, low, medium, high and very high) and nitrogen was very low (with percentage of soil organic matter 1.1-2, lower 4, 4-7, 7-10, 10-13 and higher 13 mgr per kgr nitrate was showed very low, low, medium, high and very high respectively) (havlin *et al*, 2005).

Table 1. Physicochemical and mechanical properties of the experimental area soil.

Depth	0-40cm
Texture	Clay silt
EC dS/m	1.2
pH	7.2
T.N.V%	18.4
O.C%	1.35
Pppm	11.1
Kppm	257.3
N (%)	0.275

Results and discussion

Various morphological factors in soybean dramatically were affected by potassium and magnesium treatment. The table of analyzes variance showed that the interaction between Mg and K was significant effected on plant height and reproductive period length (Table 2).

The interactions of potassium and magnesium were significant on plant height (table 2). Increasing potassium and magnesium concentration led to an increase in plant height and 200 kg/h potassium phosphor with 100 kg/h magnesium treatment had the highest plant height (Table 3 and 4) and also application of Mg effected a significant on the plant height. Increasing Mg concentration to 100 kg/h magnesium sulfate showed a positive effect on the plant height.

Data on reproductive period length showed that with increase of fertilizer concentration, there was significant increase in reproductive period length (Table 2).

The best combination of treatments and highest reproductive period length of plants were achieved from 100 kg/h magnesium with 200 kg/h potassium. As result, the highest reproductive period length was achieved from consumption of 200 kg of potassium phosphate per a hectare.

Table 2. Mean squares of various traits of soybean plants.

S.O. V	df	Plant height (x_1)	Node number (x_2)	Number of lateral stem (x_3)	Reproductive period length (x_4)	Pod number (x_5)	Pod dry weight (x_6)	Seed per pod (x_7)	1000-seed weight (x_8)	Seed yield (Y)
Replication	2	26.167**	6.00*	0.67^{ns}	18.39**	42.67**	16.67^{ns}	20.22^{ns}	32.67^{ns}	63105.56^{ns}
Mg	1	288.00**	8.00*	2.00^{ns}	98.00**	60.50**	112.50**	84.50*	180.50*	661250.00**
K	2	213.17**	4.50*	3.50^{ns}	281.06**	85.50**	74.00**	904.06**	31.50^{ns}	1443436.22**
Mg × K	2	19.50**	0.50^{ns}	0.50^{ns}	3.50**	3.50^{ns}	6.00^{ns}	15.50^{ns}	3.50^{ns}	16250.00^{ns}
Error	10	0.533	0.100	1.067	0.356	1.867	5.067	10.089	35.467	41696.356

** Significant at the 1% level; * Significant at the 5% level; ns Not significant.

Moreover, application of Mg fertilizer had a direct effect on reproductive period length in which by increasing the magnesium sulfate, this trait was increased. The highest and the lowest value of reproductive period length were achieved from control or lack of potassium or magnesium and 100 or 200 kg per hectare potassium and magnesium, respectively. (Table 3 & 4). However, potassium and magnesium fertilizer of value increased, plant height and reproductive period length improved (Fig. 1 & 2). Fig. 3 and 4 shows the variation of plant height and reproductive period length against potassium and magnesium. The relationship was direct between plant height with potassium and magnesium and reproductive period length was too.

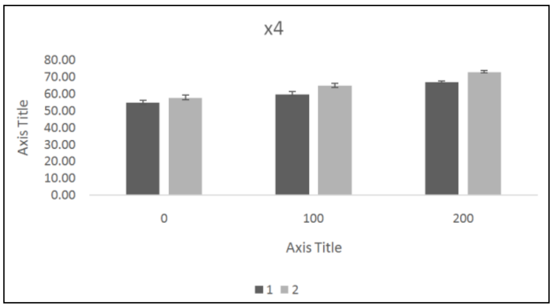


Fig. 1. Relationship between potassium and magnesium with Reproductive period length.

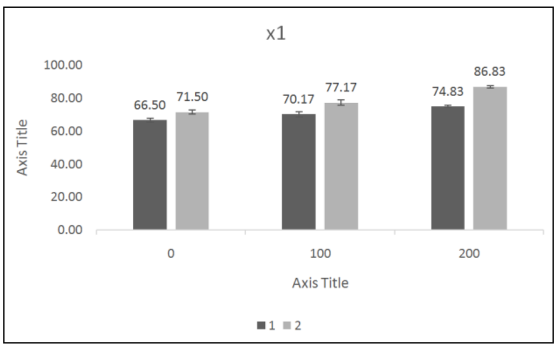


Fig. 2. Relationship between potassium and magnesium with plant height.

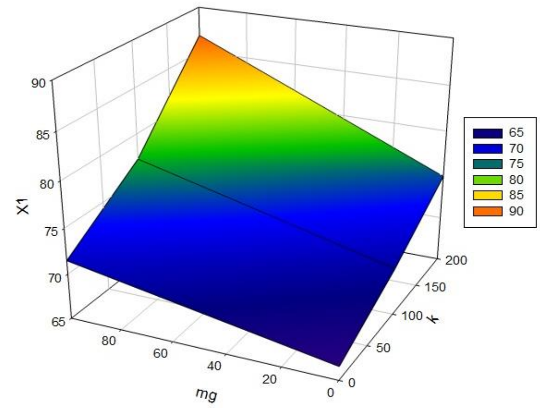


Fig. 3. The variation of X1 against Mg and K. X1; plant height, Mg; magnesium, K; potassium.

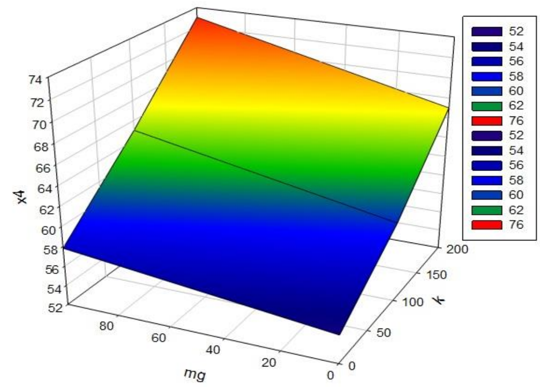


Fig. 4. The variation of X4 against Mg and K. X4; Reproductive period length, Mg; magnesium, K; potassium.

Node number was affected by main effect of treatment. The maximum number of node was obtained in the highest concentration of fertilizer application (Table 3 & 4). Indeed, the addition of fertilizer increased the number of nude of the root. There for the highest concentration of Mg or K had a positive effect on the nude production. There was no significant difference in the dry weight of seedlings between these treatments.

Number of lateral stem increased progressively as fertilizer concentration increased (Table 3 & 4). The greatest number of lateral stem was in the plants with highest treatment and the plant without the fertilizer had the lowest number of lateral steam.

Fertilizer utilization effected significantly for the amount pod number of soybean (Table 2). The highest number pod of plant was achieved from 100 and 200 kg magnesium and potassium treatment. Respectively (Table 3 & 4). Utilization of potassium and magnesium were significant on pod dry weight of plant (Table 2).

The highest pod dry weight was achieved from utilization of 100 or 200 kg per hectare potassium or magnesium treatment respectively and the lowest one was in control treatment (Table 3 & 4).

Stability of seed per pod was also affected by potassium and magnesium the highest seed per pod was achieved from utilization of 100 or 200 kg magnesium or potassium per hectare, respectively (Table 2). The lowest seed per pod was obtained from control or lack of fertilizer treatment (Table 3 & 4).

Table 3. Effect of magnesium treatments on grain yield component yield.

Mg	Plant height (x_1)	Node number (x_2)	Number of lateral stem (x_3)	Reproductive period length (x_4)	Pod number (x_5)	Pod dry weight (x_6)	Seed per pod (x_7)	1000-seed weight (x_8)	Seed yield (Y)
1	70.50 ± 1.36	15.33 ± 0.33	2.33 ± 0.33	60.61 ± 1.84	37.67 ± 1.22	42.33 ± 1.05	72.78 ± 3.24	158.33 ± 1.76	3345.56 ± 140.75
2	78.50 ± 2.33	16.67 ± 0.44	3.00 ± 0.41	65.28 ± 2.25	41.33 ± 1.55	47.33 ± 1.51	77.11 ± 4.13	164.67 ± 1.92	3728.89 ± 168.17

Table 4. Effect of potassium treatments on grain yield component yield.

K	Plant height (x_1)	Node number (x_2)	Number of lateral stem (x_3)	Reproductive period length (x_4)	Pod number (x_5)	Pod dry weight (x_6)	Seed per pod (x_7)	1000-seed weight (x_8)	Seed yield (Y)
1	69.00 ± 1.40	15.50 ± 0.43	2.00 ± 0.37	56.33 ± 1.06	36.00 ± 0.58	41.50 ± 0.99	66.33 ± 1.02	159.50 ± 3.82	3108.33 ± 85.64
2	73.67 ± 1.86	15.50 ± 0.43	2.50 ± 0.43	62.50 ± 1.34	39.00 ± 1.41	44.50 ± 1.18	69.50 ± 0.99	161.00 ± 1.39	3431.33 ± 94.83
3	80.83 ± 2.72	17.00 ± 0.58	3.50 ± 0.43	70.00 ± 1.39	43.50 ± 1.84	48.50 ± 2.14	89.00 ± 2.56	164.00 ± 1.93	4072.00 ± 157.81

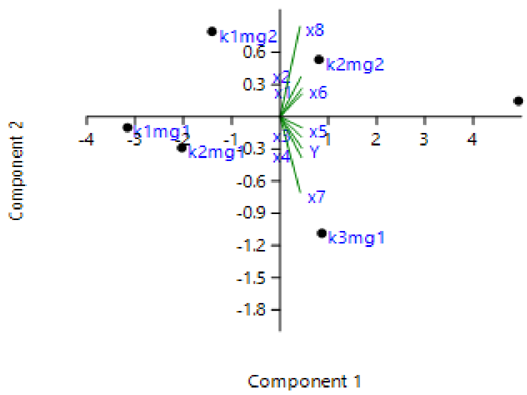
Thousand seed weight in soybean was affected by different levels of potassium and magnesium fertilizers. Adding amounts or levels of potassium increase 1000seed weight and the highest content of Thousand-seed weight was achieved from 200 kg/h potassium (Table 4).

The highest content of thousand seed weight from magnesium treatments was achieved from the highest level of magnesium utilization. When the results were compared to the control it was discovered that magnesium usage improved seed yield approximately 10 percent (Table 3). The interactions of potassium and magnesium on this trait were not significant (Table 2).

According to the result of analysis variance, soybean's seed yield was affected significantly by different levels of potassium and magnesium (Table 2). The highest seed yield was achieved (3728.89 and 4072. Kg/h) from 100 or 200 kg/h potassium or magnesium respectively (Table 3 & 4).

The comparison of fertilizer usage and control treatment on seed yield depicted that application of fertilizer increased seed yield significantly (Table 2).

The relationship among PC scores and measured trait in current research are given in table 5. Table 6 presented the percentage coefficient among PC scores and fertilizer treatment. Also Fig. 5 display bi plot for different treatment. This fig. shows that seed yield was correlated with K_2Mg_2



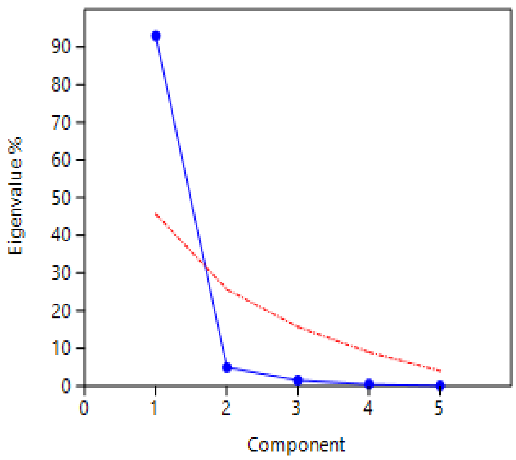


Fig. 5. (a) Graphic display biplot for different treatments based on 9 traits and (b) Scree plot showing eigenvalues in response to number of components for the estimated variables of soybean plants.

In our experiment seed yield had a positive and significant correlation with plant height, node number, reproductive period length, pod number, seed per pod and Thousand-seed weight. Results showed that Thousand-seed weight had a positive and significant correlation at P>0.01 with node number and Pod dry weight, which is an indication of the connection between the content of these parameter. Among of yield components, the highest correlation Coefficient of seed yield observed with Seed per pod (0.953). This subject expressed that most effective factor on seed yield was Seed per pod (Table 7).

Table 7. A matrix of simple correlation coefficient ® for the estimated variables of soybean plants.

	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(Y)
Plant height (x_1)	1								
Node number (x_2)	0.551*	1							
Number of lateral stem (x_3)	0.644**	0.31	1						
Reproductive period length (x_4)	0.949**	0.498*	0.671**	1					
Pod number (x_5)	0.909**	0.28	0.645**	0.899**	1				
Pod dry weight (x_6)	0.790**	0.832**	0.25	0.749**	0.545*	1			
Seed per pod (x_7)	0.780**	0.723**	0.42	0.850**	0.657**	0.834**	1		
1000-seed weight (x_8)	0.46	0.642**	0.05	0.37	0.46	0.613**	0.46	1	
Seed yield (Y)	0.842**	0.765**	0.36	0.871**	0.670**	0.949**	0.953**	0.548*	1

Mengel and Kirkby, 2001 found that application of potassium fertilizer increased morphological traits of soya bean. Mirzapor *et al.*, 2003 reported that application of potassium and magnesium had positive interactions on yield of safflower. Sawan *et al*, 2006 reported that utilization of potassium improved cotton seed yield. This was possible because of its positive effects on yield components of cotton (for instance number of cotton-pods and cotton-pod weight or both). Utilization of potassium fertilizer with nitrogen and phosphorus increased Sesame yield components (Sharma, 2005). Potassium had positive and direct effects on metabolism of nucleic acids, proteins and other underlying growth materials (Bednarz and Austerhyus, 1999).

These results show that potassium might have replaced the magnesium, as suggested by some researchers (Mitra *et al.*, 1990; Singh 1987; Hirokiand Fuji1984; Desmukh, S., 1975). Dwivedi and Patel (1990) obtained a maximum rice yield with 80 kg K/ha.

The Mg and K application improved the plant height of soybean, (Table 3 and 4). These results agreed by (Parks, 1985) who indicated that plant height is primarily increased with K application. According to the correlation analysis, the plant height was significantly positively correlated with plant yield (Table 7).

Compared with the control treatment (zero-K), the K application increased the plant height. Wakhloo (1975) observed that the improvement in plant height resulted ® by environmental and soil conditions, plant type and nutrient management. so, under optimal fertilizers application such as occurred for this study, available means to increasing height of the plants is to applied the K of 200 or100 kg Mg/ha.

Thousand seeds weight, pods per plant and seed yield reached maximum levels when soybean was planted at the treatment of 100 Kg/h K or 200 Kg/h Mg. The possible reason might be that at the levels of Mg or K application most plants were vigorous and absorbed the nutrients more efficiently. Our results are in agreement with those of Mabapa *et al.*, 2010; Kamara *et al.*, 2008; Deliboran *et al.*, 2011 reported similar findings of higher Thousand seeds weight, pods per plant and seed yield of soybean under the condition of the proper K and/or Mg application. The decrease in leaf area, 1000seeds weight, pods per plant and seed yield at the lowest Mg or K application was most likely due to the growth development of soybean was influenced by nutrient deficiency. Our results agreed by Bly *et al.* (1997), Kamara *et al.* (2007) found that proper nutrient improve the shoot uptake and increase shoot dry matter weight, thousand seeds weight, pods per plant and yield. Chiezey *et al.* (2009) suggested that the nutrients application stimulated leaf expansion, hence more light interception for photosynthetic activity, high assimilated accumulation and seed yield, pod yield and thousand seeds weight which are important determinants of seed yield increased. These caused increase seed yield. On the other hand, the decrease in leaf area, thousand seeds weight, pods per plant and seed yield at low nutrients application might be due to the shortage of nutrients availability to plants due to the strong competition among the plants (Duncan, 1984) that limited the growth improvement of soybean. Increase in soybean leaf area with application of proper K is also reported by Kolar and Grewal, 1994.

Application of Mg insignificantly increases all growth parameters as compared with control treatment. These results agreed by Basole *et al.*, 2003; Gupta *et al.*, 2003; Kassab, 2005. It can be concluded also that the enhancement effect of spraying mungbean plants with Zn, K or Mg on growth parameters was very clear, hence treated plants resulted in taller, greater number and weight of leaves, branches, pods/plant. Such enhancement effect might be attributed to the favorable influence of these nutrients on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants (Tausz *et al.*, 2004).

From the previous discussion, it should be clear that a properly managed K fertility program is essential to achieve the maximum crop productivity. When soil and plant K levels are not maintained at sufficient levels, economic losses can occur because of reduced production of grain, fiber or biomass.

Much of this yield loss can be attributed to the aforementioned reduced overall production of photosynthetic assimilates when potassium levels are insufficient. To achieve or maintain maximal maize yields, supplemental K fertilization is often required, particularly on soils testing low for native available soil K. Many researchers have reported maize yield increases in response to K fertilization (Ebelhar and Varsa, 2000; Heckman and Kamprath, 1992; Mallarino *et al.*, 1999).

Potassium fertilization also elicits responses in soybean plants. These potassium fertilization responses can be achieved under a number of management regimes when the soil tests low for available K. increasing Soybean yield can be obtained with K fertilization when grown under conventional tillage (Casanova, 2000), conservation tillage (Nelson *et al.*, 2005), when the fertilizer was banded or broadcast (Yin and Vyn, 2002, 2003, 2004), and sometimes when the K is applied in a foliar application (Nelson *et al.*, 2005).

The positive yield response to K can be attributed to increases in most of the yield components. The number of pods per plant (Bharati *et al.*, 1986) and the weight of individual seeds (Bharati *et al.*, 1986) increased in response to K fertilization. Coale and Grove (1990) found that increasing soybean yield was under high K fertility because of increasing production of both total and main stem pods per plant and more seeds per pod. They did not find an increase in seed size in response to Kas Bharati *et al.*, 1986 reported.

Conclusions

Potassium and magnesium treatments and its interaction were effective significantly on plant height and Reproductive period length in one percent level. But did not affect significant on Number of lateral stem. These treatments improved crop yield and yield components. With adding potassium and magnesium fertilizers to soil, plant height, Reproductive period length and Seed yield increased. Among of yield components, the most effective factor on seed yield was Seed per pod. It suggested that simultaneous application of potassium fertilizer with ammonium fertilizer caused increased potassium uptake by root and seed yield.

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