African Journal of Biotechnology Vol. 9(25), pp. 3769-3774, 21 June, 2010
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2010 Academic Journals

Full Length Research Paper

Growth and yield responses of *Sphenostylis stenocarpa* (Hochst ex. A Rich) Harms (African yam bean) to potassium application

G. C. Mgbeze[1]* and B. Ikhajiagbe[2]

[1]Department of Botany, University of Benin, Benin City, Edo State, Nigeria.
[2]Raw Materials Research and Development Council, Abuja, Nigeria.

Accepted 13 April, 2010

Responses of African yam bean (*Sphenostylis stenocarpa*) to supplementary application of potassium (K) on soil were examined. Effects of the varying levels of potassium on vegetative growth, flowering, pod maturation, yield and yield components were also evaluated. There seems to be no significant mean effect ($P > 0.05$) upon K application on the above ground parameters of African yam bean. Similarly, soil enrichment with K had no significant effect ($P > 0.05$) on below ground parameters of the crop. Mineral elemental applications had no significant effect ($P > 0.05$) on days to 50% flowering but their effect on the number of flowers per plant for example 192.75 ± 9.87 flowers per plant in 550 kg K/Ha treatment as against 145.13 ± 18.02 flowers per plant in the control treatment were significantly different. However, grain yield per hectare increased significantly ($P < 0.05$) with increasing levels of K application when compared to controls.

Key words: African yam bean, mineral, potassium, grain, yield.

INTRODUCTION

The African yam bean (*Sphenostylis stenocarpa*) is a climbing legume that grows to a height of over 3 m and is adapted to lowland tropical conditions. It is one of the lesser known legumes (Ikhajiagbe et al., 2007a,b; Apata and Ologhobo, 1990) and widely cultivated in the southern parts of Nigeria for its edible seeds and tuberous roots (Okigbo, 1973). The African yam bean is also cultivated in many other parts of Africa. The leaf and floral arrangements as well as the shape and color of seeds of this crop have been determined (Okigbo, 1973; Klu et al., 2000; Ikhajiagbe, 2003; Ikhajiagbe et al., 2007a,b). The leaves are stipulate with petioles 4 - 8 cm and rachis 1-3 cm. The African yam bean is partly cultivated in very poor soils often mixed plantings with yams, maize, okra and other vegetables (Okigbo, 1973). Some farmers resort to mineral nutrients supplementation in such cases.

We had earlier established that phosphate enrichment of soil enhanced grain yield to the tune of 1509.02 kg/ha when 330 kg/ha super phosphate with absolute amount of phosphorus (P) being 46% of super phosphate (P_2O_5) per weight was applied compared to control treatment value of 1104.83 kg/ha (Ikhajiagbe et al., 2009). Potassium occurs in the soil in three forms: as exchangeable (available) potassium (K^+) adsorbed onto the soil cation exchange capacity (CEC); fixed by certain minerals from which it is released to available form very slowly; and in unavailable mineral forms (most of the potassium in soils). Plants take up potassium as K^+ ion (Wallingford, 1980; Bergmen, 1985). The common source of potassium fertilizer is muriate of potash (0 – 0 – 60), which chemically is potassium chloride (KCl) and it is highly water-soluble. At high concentration, muriate of potash can cause salt damage to plants (Beegle, 1990).

Potassium is regarded as one of the most important nutrients for plants because it plays an important role in water transportation, photosynthesis and other metabolic activities throughout plant growth and development. Losses of soil potassium (K) in Nigeria are serious due to high temperature, high rainfall and intense soil weathering

*Corresponding author. E-mail: gcmgbeze@yahoo.com.

Abbreviations: CEC, Cation exchange capacity; **MOP,** muriate of potash; **WAP,** weeks after planting.

and leaching. In addition, high cropping index removes large quantities of plant nutrients from the soil. Hence, there are large areas of K deficient cultivated soils and this area has expanded in recent years. All these factors make K an important limitation to sustained production of high crop yields and quality. The objective of this study is to assess the effects of supplementary application of potassium to *S. stenocarpa* on growth and yield of the crop.

MATERIALS AND METHODS

The study was carried out in the Ugbowo campus of the University of Benin, Benin City, Edo State, Nigeria which lies within the rainforest ecological zone of Midwestern Nigeria with an annual rainfall of 1825 mm and on latitude 6° 36' and longitude 6° 19'. Soil physiochemical composition of the experimental site determined prior to the experimentation was as follows: pH H_20: 5.63; carbon: 3.87%; total N: 20.62 ppm; NO_3: 15.10 ppm; P: 36.54 ppm; K: 3.54 meq/100 g; Ca: 2.33 meq/100 g; CEC: 8.42 meq/100 g; sand: 64.46%; silt: 24.38%; clay: 11.16%, (Ikhajiagbe et al., 2007a). The plot consisted mainly of guinea grass (*Panicum maximum*) prior to cultivation.

Land preparation and sowing

The experimental plot was cleared and tilled by properly mixing the soil. Topsoil was placed in oil palm nursery bags measuring 30 x 2.5 cm. Planting was done on May 20, 2004. Seeds were sown at the rate of 4 seeds per hole and at a depth of 3 cm (Mayhew and Penny, 1988) and spaced on the field 60 and 30 cm, as proposed by Okeleye et al. (1999), amounting to 55, 000 stands per hectare. When seedlings attained 2-leaf stage (8 - 12 cm long), they were thinned down to 2 seedlings per bag.

Plant nutrient application

The source of potassium for the purpose of the present study was muriate of potash (MOP), with absolute amounts of K being 60 – 62%, K_2O per unit weight of muriate of potash (Beegle, 1990). MOP was applied 3 weeks after planting (WAP) in a band, very close to the circumferences of the nursery bags (Yin and Vyn, 2003) and application was at 5 different levels: 2, 4, 6, 8 and 10 g per nursery bag, amounting to 110, 220, 330, 440, and 550 kg (K)/ha. The control experiment was not supplemented with any mineral elements (0 kg K/ha).

Crop husbandry

The plot was weeded thrice before harvest. Although the plants were exposed to the prevailing weather condition (rainy season of April – August, 2004), water requirements by the crop were supplemented during very dry days by the addition of 200 ml distilled water applied per nursery bags beyond sunset. When plants were long enough, they were staked on bamboo poles.

Parameters determined

Shoot height was measured from the soil level to the tip of the plant using a meter rule. Number of shoot branches and number of leaves were counted *in situ*. Leaf area was determined using the graph sheet method as described by Eze (1965). Chlorophyll content was measured using the method described by Holden (1965). Root length was measured after irrigating and carefully uprooting the plants with meter rule. The number of primary root branches, number of root nodules and weight of ten root nodules were determined. Plant dry weight was determined after drying to constant weight at 70°C. Yield parameters namely: length and number of reproductive branches, length of pod, days to 50% flowering and total numbers of flowers were determined following the methods of IBPGR and ICRISAT (1993). Other parameters measured were number of pods per plant, number of seeds per pod, 100 seeds weight and estimated grain yield.

Experimental design

The experimental design adopted was the completely randomized design (CRD) following assumption of homogeneity of the experimental plot in use. As a result, treatments were randomized over the whole plot. Each treatment consisted of 16 replicates.

RESULTS AND DISCUSSION

There was no significant mean effect ($P > 0.05$) upon K supplementation on plant height of African yam bean at 9 WAP when compared to the control treatment. Plant height increased significantly ($P < 0.05$) from 107.57 ± 4.06 cm in the control to 117.23 ± 5.03 cm in 550 kg (K)/ha treatment (Table 1). Significant higher mean leaflet area value was recorded at the highest level, 550 kg (K)/ha only. No significant mean effects were recorded on number of primary shoot branches, number of leaves per plant and total leaf chlorophyll.

Mineral nutrient supplementation had no significant ($P > 0.05$) effect on the length of main roots as well as on the number of primary root branches, weight of root nodules per plant of African yam bean (Table 2). However, number of roots nodules per plant increased significantly ($P < 0.05$) from 23.00 ± 1.31 g in 110 kg K/ha to 25.63 ± 1.56 g in 550 kg K/ha treatment as against 21.38 ± 1.63 g in control treatment.

Soil enrichment with K increased total plant dry weight from 13.45 ± 1.08 g in 110 kg K/ha to 17.44 ± 1.39 g in 550 kg K/ha as against 13.17 ± 0.79 g in the control at ($P < 0.05$) as shown in Table 3. Similar significant increases were recorded in shoot to root ratio, with the highest shoot: root ratio of 30.43 in 330 kg K/ha treatment as against 20.73 in the control treatment. Hunt (1990) had reported that shoot to root ratios in many herbaceous plant species decline throughout much of their vegetative growth and development. When resources are limiting, plants grow and develop slowly, retaining the lower shoot: root ratios of less developed plants.

Higher levels of K significantly increased number of reproductive branches to 7.42 ± 0.94 cm in 550 kg K/ha as against 5.83 ± 0.39 cm in the control treatment ($P < 0.05$). No significant change ($P > 0.05$) in the length of the same structure was however recorded (Table 4). Increasing K concentration significantly ($P < 0.05$) reduced time taken for first floral initiation in African yam bean

Table 1. Effects of K application on above ground parameters of African yam bean (*S. stenocarpa*).

Treatment area[1] (cm^2) kg K/ha	Shoot height[1] (cm)	No. of pry shoot branches[1]	No. of leaves/ plant	Leaf	Total Chl[2] (mg/g)
0 (Control)	107.57 ± 4.06 b	4.06 ± 0.23 a	17.77 ± 0.74 b	55.49 ± 1.04 b	3.47 ± 0.07 a
110	111.36 ± 4.34 b	4.13 ± 0.20 a	18.15 ± 0.95 b	55.84 ± 1.28 b	3.36 ± 0.12 a
220	110.88 ± 4.39 b	3.88 ± 0.18 a	17.77 ± 0.93 b	55.85 ± 1.06 b	3.45 ± 0.11 a
330	113.79 ± 5.01 b	3.75 ± 0.17 a	18.31 ± 1.02 b	56.82 ± 1.92 b	3.50 ± 0.07 a
440	112.81 ± 4.95 b	4.06 ± 0.19 a	18.31 ± 0.85 b	56.56 ± 1.46 b	3.26 ± 0.16 a
550	117.23 ± 5.03 a	4.00 ± 0.20 a	18.77 ± 0.88 b	58.06 ± 1.56 c	3.34 ± 0.17 a

[1]Mean ± standard error for 16 determinations; [2]mean ± standard error for 8 determinations.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

Table 2. Effects of K application on below ground parameters of African yam bean (*S. stenocarpa*).

Treatment kg K/ha	Root length[1] (cm)	No. of pry root branches[1]	No. of root nodules/plant[2]	10 nodules weight[2] (mg/g)
0 (Control)	57.48 ± 3.79 a	5.75 ± 0.23 b	21.38 ± 1.63 a	0.09 ± 0.01 a
110	55.18 ± 3.34 a	5.00 ± 0.53 b	23.00 ± 1.31 a	0.07 ± 0.01 a
220	60.80 ± 1.57 a	6.88 ± 0.72 b	22.75 ± 1.44 a	0.08 ± 0.01 a
330	61.92 ± 2.39 a	6.25 ± 0.53 b	24.38 ± 1.27 a	0.08 ± 0.01 a
440	61.14 ± 5.50 a	5.63 ± 0.49 b	24.75 ± 1.64 a	0.08 ± 0.01 a
550	60.11 ± 4.72 a	5.50 ± 0.53 b	25.63 ± 1.56 a	0.08 ± 0.01 a

[1]This parameter was determined at 15WAP; [2]parameter was determined at 5 WAP.
Results are mean ± standard error for 8 determinations.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

Table 3. Effects of K application on plant dry matter accumulation of African yam bean (*S. stenocarpa*) at 9 WAP.

Treatment (K)/ha	Plant dry weight[1] (g)	Root dry weight[1] (g)	Shoot : root ratio[2]
0 (Control)	13.17 ± 0.79 c	0.619 ± 0.030 c	20.73
110	13.45 ± 1.08 c	0.604 ±0.021 c	21.27
220	15.26 ± 1.26 c	0.595 ± 0.034 c	24.65
330	18.51 ± 1.32 a	0.589 ± 0.028 c	30.43
440	16.36 ± 1.18 b	0.596 ± 0.024 c	26.45
550	70.44 ± 1.39 b	0.579 ± 0.031 c	29.12

[1]Mean ± standard error for 16 determinations; [2]mean ± standard error for 8 determinations.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

from 57 DAP in the control to 50 DAP in 550 kg K/ha. Number of flowers per plant in K treated plots also significantly increased from 187 in 110 kg K/ha to 193 in 550 kg K/ha in plots as against 143 flowers per plant in the control. No significant change was however recorded for numbers of days to 50% flowering. Percentage fruit setting, recorded as the percentage of the total number of flowers per plant that developed successfully into viable pods, increased with increasing concentrations of K applications. The present findings are in agreement with Joiner (1983), Jones (1983) and Bergman (1985) who reported that high potassium levels were required for fruit production in most crops.

Although K applications did not significantly affect time to 50% maturity, higher levels of K significantly ($P < 0.05$) delayed maturity period by two (2) days (Table 5).

Table 4. Effects of K application on flowering traits of African yam bean (*S. stenocarpa*).

Treatment kg K/ha	No of Reprod. branches/plant[1]	Length of reprod. branches[1] (cm)	Days to 50% flowering[2] (DAP)	No. of flowers/ plant[2]	Av. Fruiting setting[3] (%)
0 (Control) b	5.83 ± 0.39 b	22.59a±1.21 a	71.13 ± 1.01 b	145.13 ± 18.02	12.62
110	5.75 ± 0.43 b	19.00 ± 1.02 b	70.50 ± 0.68 a	187 ± 15.27 b	10.59
220 b	6.08 ± 0.43 b	21.08 ± 0.92 a	70.25 ± 0.93 a	192.38 ± 12.13	12.54
330	6.42 ± 0.26 b	20.44 ± 13.86 a	70.75 ± 0.75 a	184 ± 11.11 b	11.38
440 b	7.17 ± 0.41 a	21.49 ± 1.59 a	70.88 ± 1.08 a	186.75 ± 12.92	13.12
550	7.42 ± 0.94 a	21.70 ± 0.76 a	69.63 ± 0.56 ab	192.75 ± 9.87 a	12.97

[1]Mean ± standard error for 16 determinations; [2]mean ± standard error for 8 determinations; [3]calculated as percentage of mean total number of flowers per plant that developed into viable pods.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

Table 5. Effects of K application on pod initiation maturation of African yam bean (*S. stenocarpa*).

Treatment (kg (K)/ha	Days to 1st pod formation[1] (DAP)	Days to 1st pod maturity[1] (DAP)	Day to 50% maturity[1] (DAP)	Maturity period[1] (days)
0 (Control)	56.88 ± 4.18 a	64.25 ± 1.74 a	86.69 ± 1.08 a	39.06 ± 0.81 a
110	53.63 ± 1.08 b	64.19 ± 0.99 a	89.25 ± 1.73 a	38.50 ± 0.75 b
220	53.44 ± 1.05 b	64.88 ± 1.26 a	85.88 ± 1.12 a	39.13 ± 0.76 b
330	54.37 ± 1.05 a	64.63 ± 1.00 a	85.75 ± 1.26 a	39.19 ± 0.69 b
440	52.94 ± 1.02 b	63.44 ± 1.06 a	88.13 ± 1.28 a	40.50 ± 0.69 b
550	52.18 ± 0.88 b	63.44 ± 0.88 a	86.00 ± 1.13 a	40.94 ± 0.69 b

[1]Mean ± standard error for 16 determinations.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

Table 6. Effects of K application on yield parameters of African yam bean (*S. stenocarpa*).

Treatment kg K/ha	No. of pod/plant[1]	Pod length[1]	No. of seeds/pod[1]	100 seed weight[2]	Estd grain yield
0 (Control)	18.31 ± 0.62 b	16.58 ± 0.49 a	13.26 ± 0.64 b	8.28 ± 0.31 c	1104.83
110	19.81 ± 0.72 b	15.29 ± 0.56 a	14.19 ± 0.69 b	8.30 ± 0.18 c	1283.24
220 a	24.13 ± 1.32 a	17.36 ± 0.47	14.69 ± 0.78 b	8.52 ± 0.19 b	1661.05
330	20.94 ± 1.63 b	16.48 ± 0.62 a	13.50 ± 0.52 b	9.46 ± 0.39 b	1470.84
440	24.50 ± 0.89 a	18.21 ± 0.36 a	14.81 ± 1.48 b	9.62 ± 0.17 a	1919.81
550	25.00 ± 1.39 a	17.31 ± 0.56 a	14.56 ± 0.69 b	10.58 ± 0.30 a	2118.12

[1]Mean ± standard error for 16 determinations; [2]mean ± standard error for 8 determinations.
Means with same alphabets within the same column do not differ significantly (P>0.05) from the control.

Potassium supplementation had no significant effect on pod length, but significantly increased the number of pods per plant, number of seeds per pod and 100 seed weight, above 220 kg K/ha level (Table 6). Similarly, grain yield significantly increased ($P < 0.05$) with K application from 1283.24 kg in 220 kg K/ha and to 2118.12 kg in 550 kg K/ha in treated plots as against 1104.83 kg in the control treatment. These results corroborated the earlier findings of Joiner (1983), Jones (1983) and Bergman (1985).

Correlation analysis of plant traits namely, maturity period, number of pods, lengths of reproductive branch, pod length, seed/pod and plant dry weight were evaluated (Table 7). The correlation coefficient of traits in the control experiment showed a highly significant positive correlation ($r = 0.9985$) existing between length of reproductive branch and plant dry weight. Pod length was also highly correlated with seed per pod ($r = 0.95$). At 1% significance level, length of reproductive branch was correlated with maturity period of the crop ($r = 0.5016$) at 5%. However, maturity period was inversely related to pod/plant ($r = -0.1920$), pod length ($r = -0.077$) and plant

Table 7. Correlation coefficients of selected developmental characteristics of *S. stenocarpa* in the control treatment.

Parameters	Maturity period	Pods/plant	Length rep. branch	Pod length	Seed/pod	Plant dry weight
Maturity period	1.0000					
Pods/plant	-0.1920	1.0000				
Length Rep.Branch	0.5016*	0.3856	1.0000			
Pod length	-0.0770	0.1298	-0.0700	1.0000		
Seed/Pod	0.0005	0.0999	0.0055	0.9500**	1.0000	
Plant dry weight	-0.0368	0.2918	0.9985**	0.2163	0.1195	1.0000

*Significant at 0.05 level (0.4973); **significant at 0.01 level (0.6226).

Table 8. Correlation coefficients of selected developmental characteristics of *S. stenocarpa* in 220 kg (K)/ha treatment.

Parameters	Maturity period	Pods/plant branch	Length rep.	Pod length	Seed/pod	Plant dry weight
Maturity period	1.0000					
Pods/plant	-0.2985	1.0000				
Length rep. branch	0.1726*	-0.2910	1.0000			
Pod length	0.1899	-0.2090	-0.0499	1.0000		
Seed/pod	0.3664	0.3167	-0.5628	0.8748**	1.0000	
Plant dry weight	-0.0776	0.5268*	0.8725**	-0.3893	0.4041	1.0000

*Significant at 0.05 level (0.4973); ** significant at 0.01 level (0.6226).

Table 9. Correlation coefficients of selected developmental characteristics of *S. stenocarpa* in 440 kg (K)/ha treatment.

Parameters	Maturity period	Pods/plant	Length rep. branch	Pod length	Seed/Pod	Plant dry weight
Maturity period	1.0000					
Pods/Plant	-0.0667	1.0000				
Length rep. branch	0.4244	-0.2649	1.0000			
Pod length	0.3363	-0.0246	-0.2739	1.0000		
Seed/Pod	0.1481	-0.2334	0.51460	0.8774**	1.0000	
Plant dry weight	0.1241	-0.0423	0.9360**	-0.8490**	0.8500**	1.0000

*Significant at 0.05 level (0.4973); **significant at 0.01 level (0.6226).

weight (r = -0.0368).

In 220 kg K/ha treatment (Table 8), however, length of reproductive branches was inversely related to number of seeds/pod (r = -0.5628), pod length (r = -0.0499), number of pods/plant (r = -0.2910) and pod length (r = -0.2909). At 5% significance level, pods/plant was positively correlated with dry weight (r = 0.5268), with higher positive correlation (P < 0.01) between length of reproductive branch and plant weight (r = 0.8725), and between pod length and seeds per pod (r = 0.8748). In 440 kg K/ha treatment (Table 9), pod length was correlated with plant weight (r = 0.8490). Similarly, length of reproductive branch was positively correlated with seeds per pod (r = 0.5146) at 5% level of significance. Plant weight was also highly positively correlated with length of branches (r = 0.9360), pod length (r = 0.8490) and seeds per pod (r = 0.8500) at 1% significance level. Inverse relationship existed between pods/plant and other 5 yield parameters under comparison.

In effect, potassium enrichment of soil enhanced the growth of *S. stenocarpa* and increased the number of flowers per hectare but delayed days to pods maturity of the crop. Also, grain yield increased with increasing K application.

REFERENCES

Apata DF, Ologhobo AD (1990). Some of the biochemistry and nutritive value of African Yam Bean seed *Sphenostylis stenocarpa*. Food Chem. 36: 271-280.

Beegle D (1990). The Agronomy Guide, 1989-1990. Department of Agronomy, Penn State: p. 32.

Bergman EL (1985). Nutrient Solution Culture of Plants. The Pennyslavia State University College of Agriculture, Extension Service Hort. Mimeo Series 2: 160.
Eze JMO (1965). Studies on growth regulations, salt uptake and translocation. Ph.D thesis, University of Durham, U.K., p. 31.
Holden M (1965). Chlorophylls. In: Chemistry and Biochemistry of Plant Pigments, Goodwin TW (ed.), Academic Press London; pp. 462-488.
Hunt R (1990). Basic Growth Analysis. Unwin Hyman, London, U.K.
IBPGR and ICRISAT (1993). Descriptors for Pigeon Pea [*Cajanus cajan* (L.) Mill sp.] International Board for Plant Genetic Resources Secretariat, Rome, and International Crops Research Institute for the Semi Arid Tropics, Indian; p. 31.
Ikhajiagbe B (2003). African yam bean in Nigeria: the stone that the builders rejected. Raw materials Digest, 1: 2-4.
Ikhajiagbe B, Mgbeze GC, Folu M, Dania O (2007a). Responses of *Sphenostylis stenocarpa* (Hochst Ex. A. Rich) Harms (African yam bean) to salinity stress I: Germination and Vegetative Growth. NJB, 20: 69-82.
Ikhajiagbe B, Mgbeze GC, Folu M, Dania Ogbe (2007b). Responses of *Sphenostylis stenocarpa* (Hochst Ex. A. Rich) Harms (African yam bean) to salinity stress II: Yield, yield components and chemical composition. NJB, 20: 83-92.
Ikhajiagbe B, Mgbeze GC, Erhenhi HA (2009). Growth and yield responses of *Sphenostylis stenocarpa* (Hochst Ex. A. Rich) Harms (African yam bean) Harms to phosphate enrichment of soil. Afr. J. Biotechnol. 8(4): 641-643.
Joiner JN (1983). Nutrition and fertilization of ornamental greenhouse crops, J. Janick (ed.). IN: Horticultural reviews, AVI Pub. Co., Inc. Westport, CT. 5: 380-403.
Jones Jr. JB (1983). A Guide for the Hydroponic and Soil less Culture Grower. Timber Press, Beaverton Oregon p. 124.
Klu GYP, Amoaley HM, Bansa D, Kumanya EK (2000). Cultivation and use of African Yam Bean *Sphenostylis stenocarpa* in the Volta Region of Ghana. Plant Genet. Resour. Newslett. 124: 13-16.
Mayhew S, Penny A (1988). Tropical and Subtropical Foods. Macmillan, London. p. 289.
Okeleye K, Ariyo OJ, Olowe VI (1999) Evaluation of early and medium duration cowpea cultivars for agronomic and grain yield. N. Agron. J. 30: 1-11.
Okigbo BN (1973). Introducing the yam bean (*Sphenostylis stenocarpa* Hochest ex A. Rich) Hams. Proceedings of the first IITA Grain Legume Improvement Workshop, Ibadan, Nigeria.
Wallingford W (1980). Functions of potassium in plants. *In* Potassium in agriculture. Potash and Phosphate Institute, Atlanta, GA. pp.10-27.
Yin XH, Vyn TJ (2003). Potassium placement effect on yield and seed composition of no-till soybean seeded in alternate row widths. Agron. J. 95: 126-132.