المركز القومي للبحوث
شعبة البحوث الزراعية و البيولوجية
قسم النبات

Response of Nonnodulating, Nodulating and Supernodulating Soybean (*Glycine Max* L.) Genotypes to Potassium Fertilizer Under Water Stress

Magdi T. Abdelhamid[1*], H. A. Kamel[2] and Mona G. Dawood[1]

[1]Botany Department, National Research Center, Dokki 12622, Cairo, Egypt
[2]Radioisotopes Department, Atomic Energy Authority, Dokki 12311, Cairo
[*]E-mail: magdi.abdelhamid@yahoo.com

23 Feb. 2010

INTRODUCTION

Soil moisture is a principal environmental factor limiting legume productivity in the tropics and sub-tropics. The lack of adequate soil moisture affects both vegetative and reproductive growth of food legumes, resulting in significant yield losses (Ramirez Vallejo and Kelly, 1998).

Water deficits could affect ion uptake and changes in the hormonal balance as well as modification of membranes and proteins (Bohnert et al., 1995).

Moreover, the effect of drought stress on plant depends not only on the characteristics (duration, intensity) of the stress but also on the timing of occurrence relative to the developmental cycle of the plant (Istanbulluoglu et al., 2009).

INTRODUCTION

Food legumes are an important component of the agricultural sectors of devolving countries due to their capacity to produce significant quantities of protein-rich seed.

Moreover, legumes could improve soil conditions by the inoculation of organic matter and biological nitrogen fixation (Sangakkara et al., 2001).

Soybean has been grown as a nutritionally valuable crop since ancient times. Recently, there have been a number of reports showing several medicinal substances in soybean as isoflavonoids and saponins (Fukushima, 2000).

INTRODUCTION

Soybean plants are sensitive to drought compared with other crop plants (Ohashi et al., 2006). Some plants respond rapidly to stress by increasing the concentration of compatible solutes (Serraj and Sinclair, 2002).

Since, compatible solutes are low molecular weight, highly soluble compounds that are usually nontoxic at high cellular concentrations (Ashraf and Foolad, 2007), and involved in osmoregulation and in protection of proteins and membranes in conditions of low water potential (Gizk, 1996).

INTRODUCTION

Nitrate tolerance occurs naturally (Betts and Herridge, 1987) and can be induced through genetic changes. Jacobsen and Feenstra (1984) used ethyl methanesulphonate (EMS) mutagenesis to generate a number of symbiotically-altered mutants of pea, including a nitrate-tolerant type. Carroll et al. (1985), working with Bragg soybean, produced 15 EMS induced mutants that formed up to 40 times the number of nodules as the parent and displayed increased acetylene reduction (N2 fixation) activity in the presence of nitrate. These mutants [termed nts (nitrate-tolerant symbiotic)] were also described as supemodulators because they produced greater numbers of nodules in the absence of nitrate and appeared to be defective in the autoregulatory control of nodulation (Delves et al., 1986, 1987).

Nitrogen fixation by leguminous plants is very sensitive to changes of chemical and physical conditions in soil. Either deficit soil-moisture or excess critically restrict N_2 fixation activity of nodule bacteria and thereby markedly reduce seed yield (Harper, 1987).

INTRODUCTION

Potassium has an important role in several physiological processes directly related to nodulation and N_2 fixation as well as carbohydrate transport (Becker et al., 1991) and incorporation of combined nitrogen into protein (Feigenbaum and Mengel, 1979).

Moreover, Potassium fertilization has been shown to alleviate the negative effects of water stress in sunflower (Lindhauer, 1989) and faba beans (Abdel-Wahab and Abd-Alla, 1995). K^+ promotes root growth of food legumes under water stress conditions (Sangakkara et al., 1996), mitigates the adverse effects of moisture stress in plants by increasing translocation and maintaining water balance within plants (Walker et al., 1998).

THE OBJECTIVES

To examine how can potassium fertilizer alleviate the adverse effect of water stress on the growth, nodulation, nitrogenase activity, yield and seed quality of three soybean genotypes, En 1282 (nonnodulating), Enrei (nodulating) and En-b0-1 (supernodulating).

MATERIALS AND METHODS

A pot experiment was conducted at the wire house of National Research Centre, Dokki, Cairo, from 21 May to 22 September 2007.

Five uniform air dried soybean seeds were sown along a centre row in each pot at 30-mm depth in plastic pots, each filled with about 7 kg clay soil.

At sowing, a granular commercial rhizobia was incorporated into the soil in each pot with the seeds.

The experiment was a factorial arrangement with two levels of potassium (K) fertilizers and two water conditions used.

Three Japanese soybean genotypes were used in this experiment, namely, En 1282 (non-nodulating, NN), Enrei (normal nodulating, N) and En-b0-1 (super-nodulating, SN).

Two levels of Potassium (K) were applied i.e., 25 and 150 mg K_2O per kg soil. These are equivalent to 56.2 kg K_2O ha^{-1} (recommended dose) and 337.5 kg K_2O ha^{-1}, respectively.

MATERIALS AND METHODS

Two levels of Potassium (K) were applied i.e., 25 and 150 mg K_2O per kg soil. These are equivalent to 56.2 kg K_2O ha^{-1} (recommended dose) and 337.5 kg K_2O ha^{-1}, respectively.

Control plants (well-watered, WW) were watered and maintained during the whole season up to about 80% FWC. Sixty five days after sowing (pod filling stage); soil moisture (SM) of plants was maintained at 80% FWC for control (well-watered, WW) (24 pots of each genotype, 12 pot for each K level) and no water was added to other 24 pots (12 pot for each K level) which considered as water stressed plants (WS).

At the end of 8th day of water stress initiation, the FWC reached 10 % then, plants of 6 pots of each treatment (Either watered or water stressed with K1 and K2) were used to determine plant growth, nitrogen, potassium, nodules, nitrogenase activity, relative water content, free amino acids and free proline. The other 6 pots re-watered again and used to determine plants yield and seed quality.

The data were subjected to the analysis of variance (ANOVA) and the significant differences between treatments were compared with the critical difference at 5% probability level by the Duncan's test.

Table 1. Means of shoot dry weight per plant (SDW), root dry weight per plant (RDW), shoot nitrogen (SN) and root nitrogen (RN) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at 72 days after sowing (DAS) exposed to well-watered (WW) and watert stress (WS) treatments and two levels of potassium (K) supply.

Treatment	NN				N				SN			
	SDW (g)	RDW (g)	SN (mg)	RN (mg)	SDW (g)	RDW (g)	SN (mg)	RN (mg)	SDW (g)	RDW (g)	SN (mg)	RN (mg)
SM level:												
WW	6.09a[1]	1.02a	225b	18b	7.57a	1.15a	269b	36a	6.85a	1.11a	255b	34a
WS	5.26b	1.00a	262a	29a	7.39a	1.04b	348a	39a	6.48a	1.00b	289a	35a
K level:												
K1	5.43b[1]	0.98a	219b	19b	7.21b	1.07a	285b	36a	6.46a	1.00b	255b	36a
K2	5.92a	1.03a	268a	28a	7.75a	1.11a	331a	39a	6.87a	1.11a	290a	34a

[1]Means in the same column for each treatment have the same letter are not significantly different by Duncan's test ($P < 0.05$).

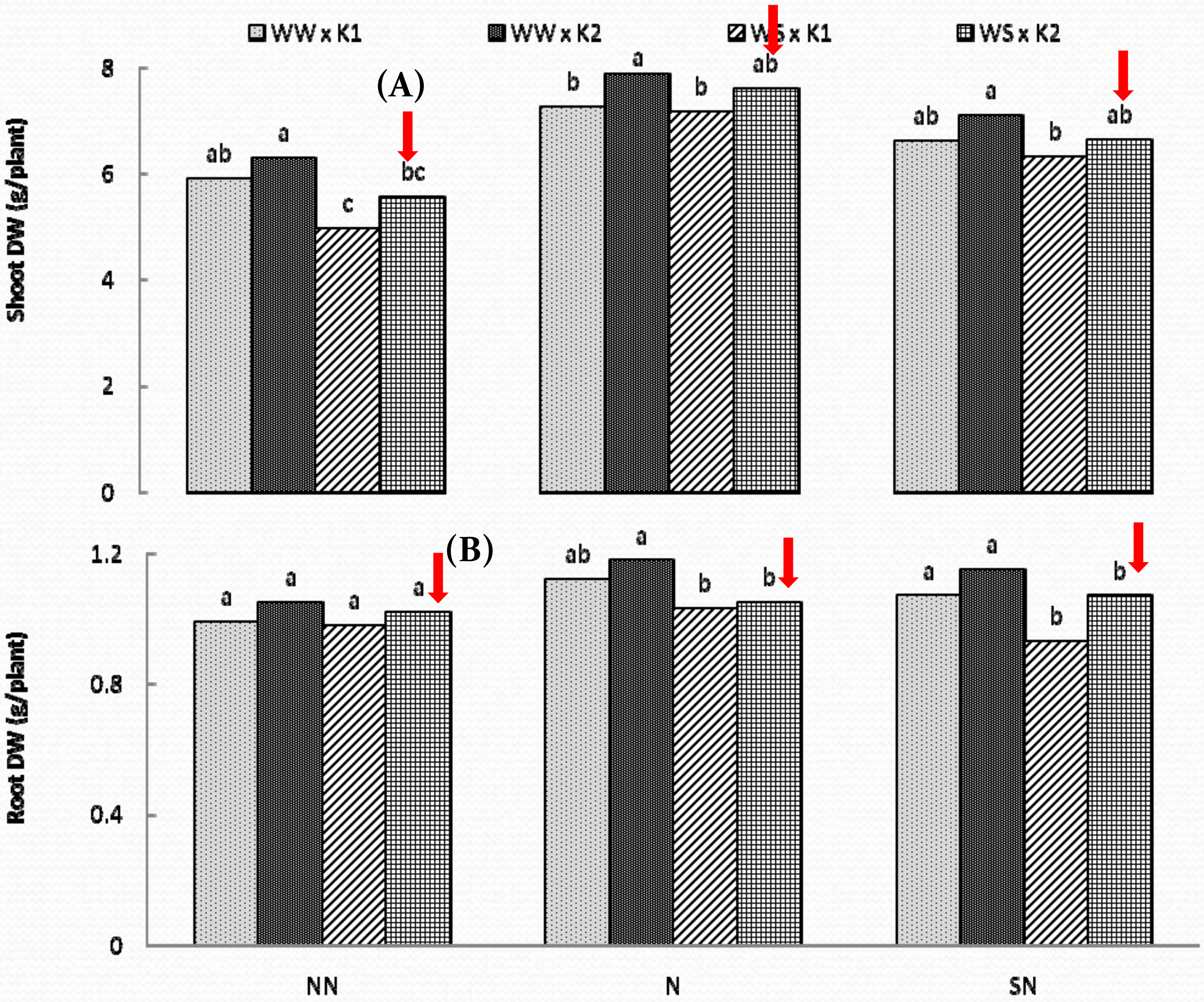

Fig.1. Interaction effects of well-watered (WW) and water stress (WS) treatments and two levels of potassium (K) supply on shoot dry weight per plant (SDW) (A) and root dry weight per plant (RDW) (B) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at 72 days after sowing (DAS).

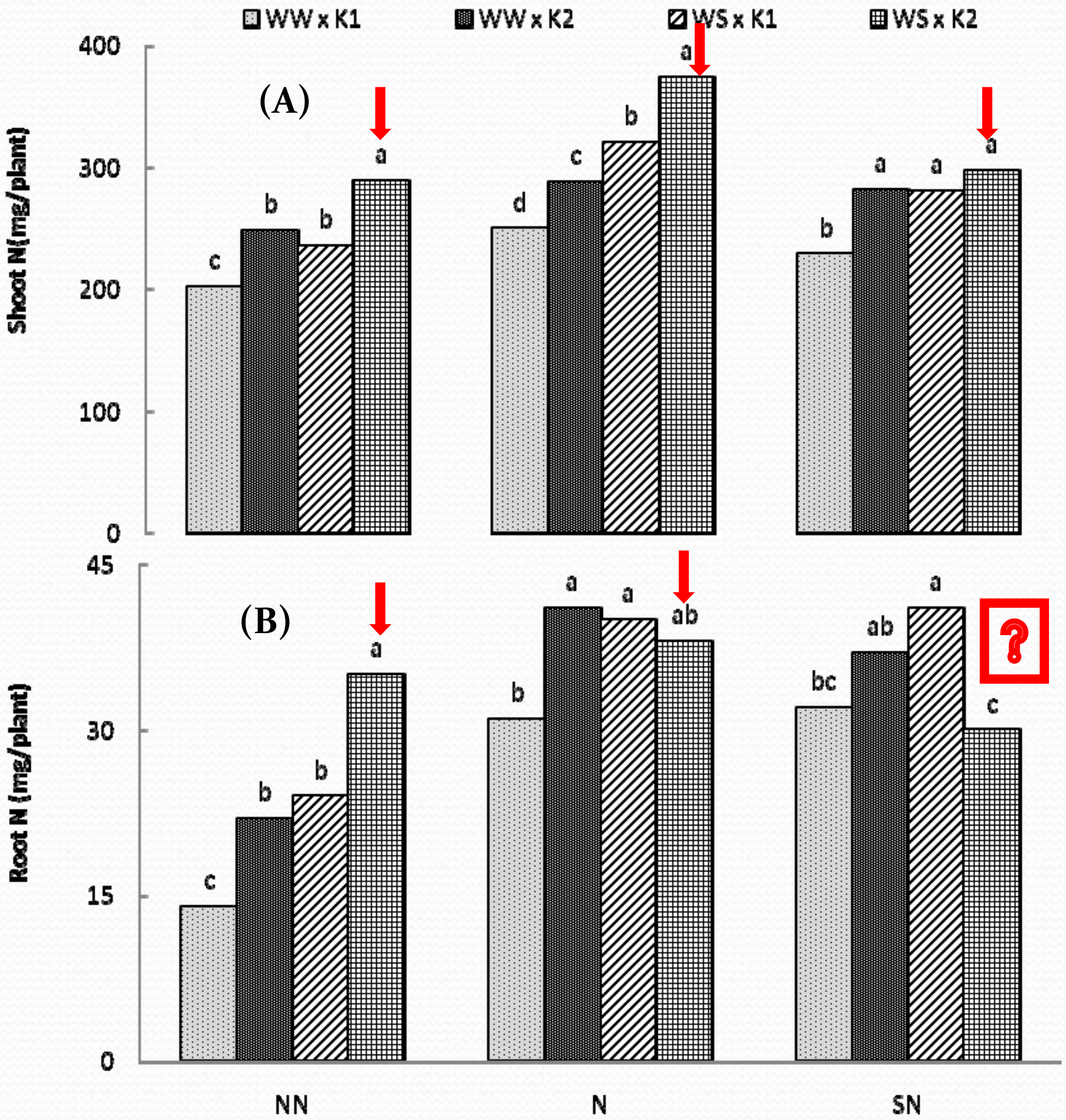

Fig.2.. Interaction effects of well-watered (WW) and water stress (WS) treatments and two levels of potassium (K) supply on shoot nitrogen per plant (Shoot N) (A) and root nitrogen per plant (Root N) (B) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at 72 days after sowing (DAS).

Table 2. Means of nodules number per plant, nodule dry weight per plant and nitrogenase activity (µmole C_2H_4/g DW nodule h^{-1}) at 72 days after sowing (DAS) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) exposed to well-watered and water-stress treatments and two levels of potassium (K) supply.

Treatment	N			SN		
	Nodule No.	Nodule DW (mg)	µ/g DW nodule h^{-1}	Nodule No.	Nodule DW (mg)	µ/g DW nodule h^{-1}
SM level:						
WW	94.0a[1]	210a		279.7a	1024a	
WS	69.7b	143b		265.3a	826b	
K level:						
K1	68.7b[1]	145b	226b	260.7a	906a	160b
K2	95.0a	207a	602a	284.3a	944a	219a

[1]Means in the same column for each treatment have the same letter are not significantly different by Duncan's test ($P < 0.05$).

Table 3. Means of Relative water content (RWC), Free Amino Acids (FAA), proline content (Pro) and Potassium (K) content of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at 72 days after sowing (DAS) exposed to well-watered (WW) and water stress (WS) treatments and to two levels of potassium supply (K) .

Treatment	NN				N				SN			
	RWC	FAA	Pro	K	RWC	FAA	Pro	K	RWC	FAA	Pro	K
		(%)				(%)				(%)		
SM level:												
WW	82.4a[1]	4.26b	1.53b	2.16b	83.9a	7.57b	1.79b	2.23a	84.2a	7.24b	2.20b	2.09a
WS	58.4b	4.60a	2.57a	2.37a	60.5a	11.08a	5.90a	1.97b	66.1b	13.87a	6.98a	2.04b
K level:												
K1	67.3b[1]	4.17b	1.30b	2.25b	71.1a	8.06b	3.14b	2.09b	74.0a	9.25b	4.05b	2.06a
K2	73.5a	4.71a	2.80a	2.27a	73.3a	10.60a	4.55a	2.12a	76.2a	11.86a	5.13a	2.06a

[1]Means in the same column for each treatment have the same letter are not significantly different by Duncan's test ($P < 0.05$).

Table 4. Means of seed yield and its chemical composition of oil content, total carbohydrate (TC) and protein (Prot) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at harvest exposed to well-watered (WW) and water stress treatments (65 to 72 days after sowing) and two levels of potassium (K) supply .

Treatment	NN				N				SN			
	Seed yield (g)	Oil (%)	TC (%)	Prot (%)	Seed yield (g)	Oil (%)	TC (%)	Prot (%)	Seed yield (g)	Oil (%)	TC (%)	Prot (%)
SM level:												
WW	2.13a[1]	21.9a	26.8a	34.1b	4.35a	20.0a	22.8a	33.7b	3.38a	19.4a	22.7a	33.1a
WS	1.93a	21.3b	25.2b	39.8a	2.37b	19.1b	20.4b	36.9a	2.28b	18.7b	21.5b	33.7a
K level:												
K1	1.52b[1]	21.9a	25.2b	36.3b	3.00a	20.0a	21.1a	34.4b	2.78a	19.6a	21.7b	33.0b
K2	2.55a	21.2b	26.9a	37.6a	3.72a	19.0b	22.0a	36.2a	2.88a	18.4b	22.5a	33.9a

[1]Means in the same column for each treatment have the same letter are not significantly different by Duncan's test ($P < 0.05$).

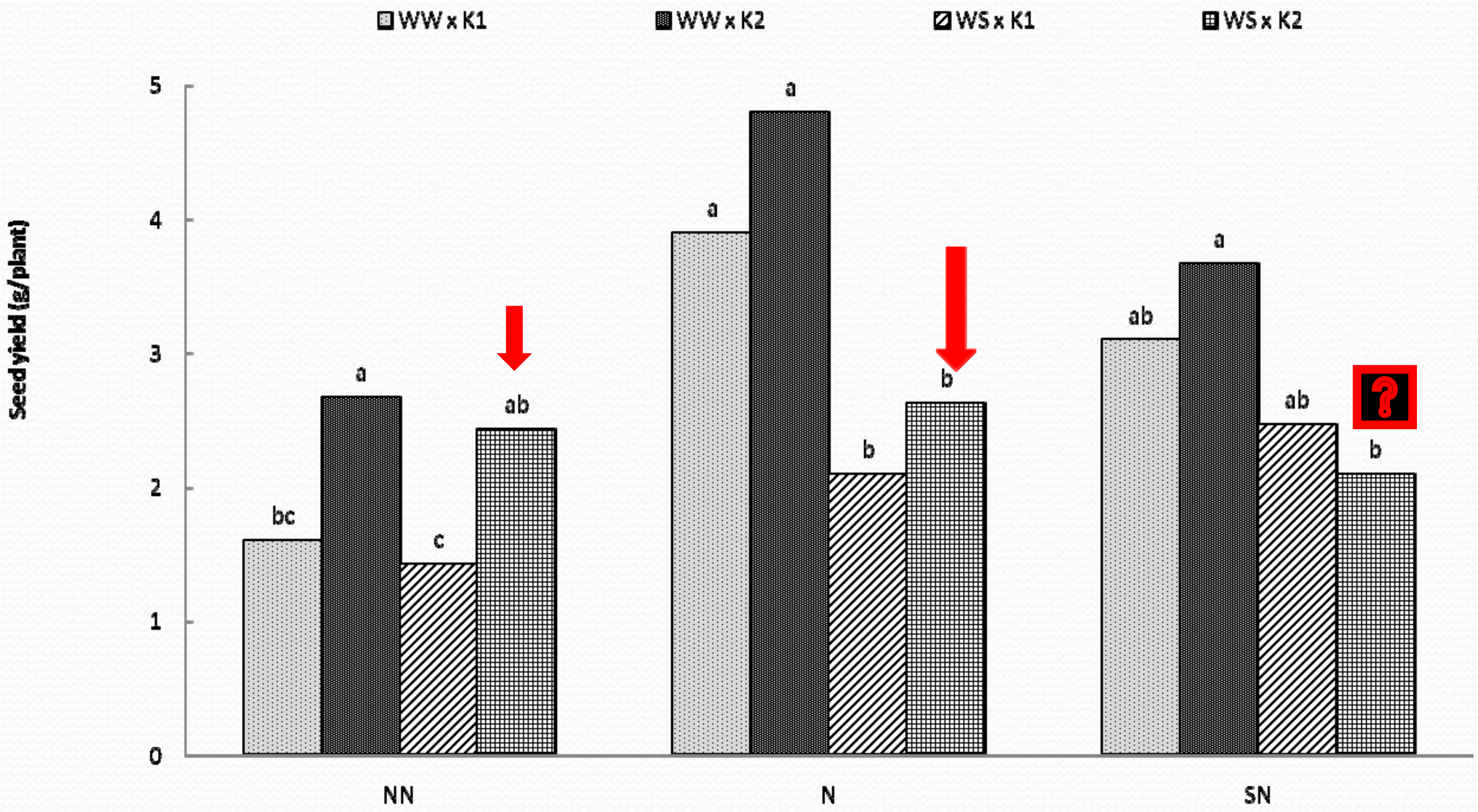

Fig.3. Interactive effects of well-watered (WW) and water stress (65 to 72 days after sowing) treatments and two levels of potassium (K) supply on seed yield of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at harvest.

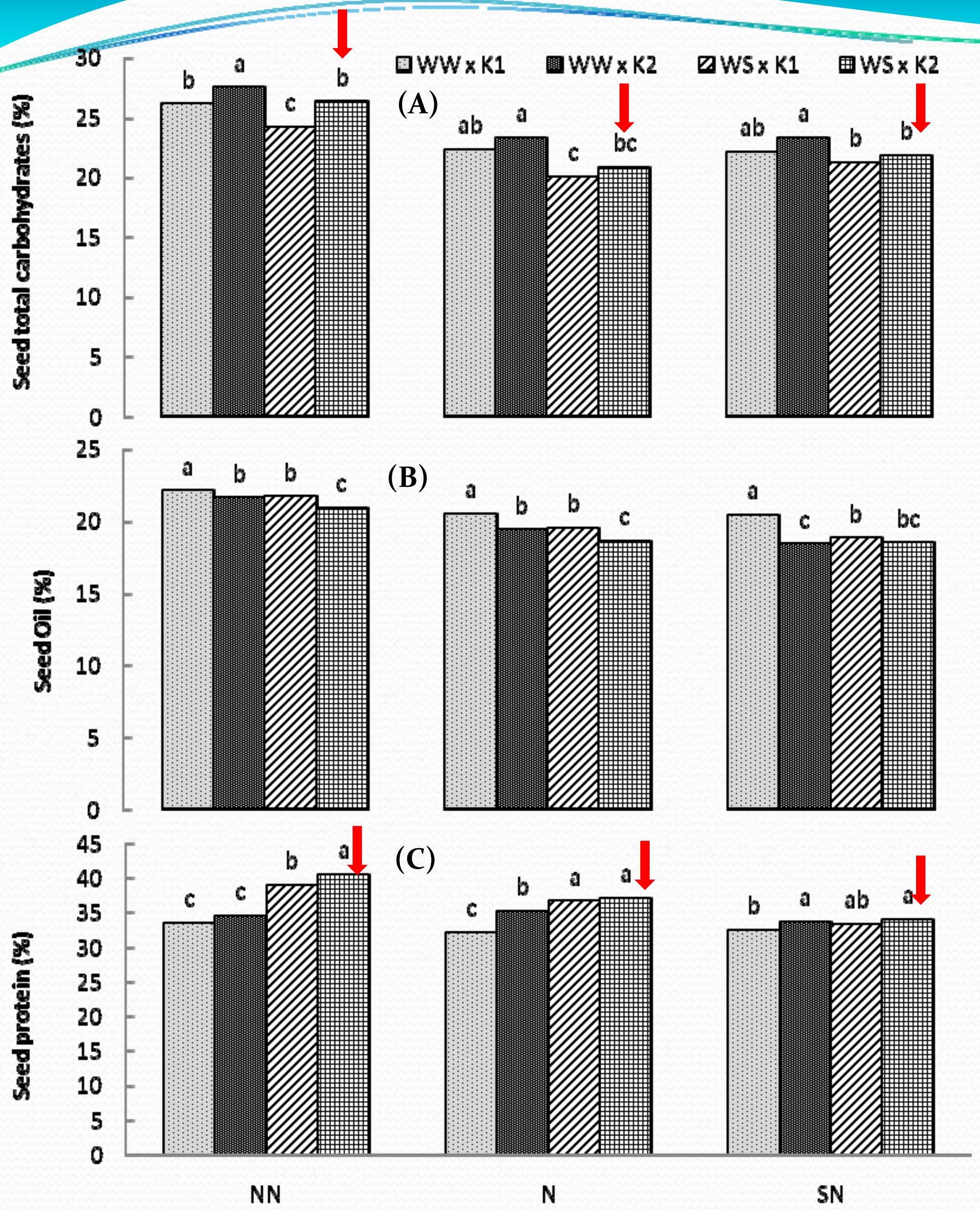

Fig.4. Interactive effects of well-watered (WW) and water stress (65 to 72 days after sowing) treatments and two levels of potassium (K) supply on seed total carbohydrate (TC), seed oil content, and seed protein (Prot) of three soybean genotypes, non-nodulating (NN), nodulating (N) and supernodulating (SN) at harvest.

CONCLUSION

Water stress adversely affected most of the studied traits.

Application of potassium mitigated the adverse effect of water stress, which facilitated the conditions that favored more or higher growth and yield levels of soybean crop.

ACKNOWLEDGMENT

Dr. Magdi Abdelhamid is grateful to National Institute of Crop Science, Japan for providing soybean seeds to undertake this study.

Thank you for your attention