

## Evaluation of Soybean Yield Under Drought Stress by Path Analysis

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**Abstract:** Soybean yield reduced by drought stress due to decreases in yield components. Our objective was to apply path analysis for determine the relationships between yield and yield components of soybean at normal and stress conditions. Therefore, an experiment based on randomized complete block design with three replications was performed in the research field of the Islamic Azad University of Kermanshah, Iran at 2009. Soybean cultivars were sown at two separate experiments normal and stress conditions. The results of stepwise regression analysis in normal site shown that pod/plant had the most effective role on soybean yield and as the first variable that entered in model explaining 63% of total variations of yield. While, in stress site seed/plant explaining 77% of total yield variations and recognized as the most important yield component. Results of path analysis showed that in normal condition, direct effect on yield were greatest for number of pod per plant (0.763\*\*), while, in stress site this value belonged to number of seed per plant (0.664\*\*). In addition, in normal site, indirect effect of pod/ plant on yield via the number of node per plant (0.648) and number of seed per plant (0.708) was greater than the other yield components. Also, for stress site seed/plant had indirect effect on yield via number of node per plant (0.588), number of pod per plant (0.579) and 100-seed weight (0.479). Number of node per plant in normal conditions had direct and negative effect on soybean yield.

**Key words:** direct effect, indirect effect, path analysis, stress conditions, and yield.

### INTRODUCTION

Drought stress is the most important abiotic stress in soybean production in Western part of Iran. Soybean yield is determined by number of pod per plant, number of seed per pod and seed weight (Ohashi and Nakayama, 2009) and these yield components are the important sink for assimilates at reproductive stages (Nobuyasu *et al.*, 2003). Also, partitioning and translocation of assimilates is dependent to water availability in soil (Mohapatra *et al.*, 2003; Wardlow and Wilenbrink, 1994; Schnyder, 1993; Whan *et al.*, 1991). Thus, soybean yield reduce due to disorder in partitioning and translocation of assimilates (Kim *et al.*, 2000). Pod and seed number per plant are correlated with assimilates transport from the source into sink (Schussler and Westgate, 1995; Kobraee and Shamsi, 2011a; Kobraee and Shamsi, 2011b). However, Water deficit at early of flowering and pod set increased flower and pod abortion (Osborne *et al.*, 2002) and at seed filling period reduced seed weight (Vieira *et al.*, 1992). In addition, drought stress increasing leaf senescence and indeed reduces source size in plant (De Souza *et al.*, 1997; Kobraee and Shamsi, 2011c). Analysis of yield components arranges groundwork for identifying effective characteristics toward yield improvement (Kobraee *et al.*, 2010). Board *et al.*, (1999) reported that yield components of soybean can be classified into primary (seed number and seed size), secondary (seed per pod and pod number) and tertiary (node number and its characteristics and pod number per node) yield components. They are emphasized that common statistical techniques cannot determine the relationships between yield and its components. Direct and indirect effects of these components on final yield can be determined by standardized partial regression coefficients in path analysis technique. For diagnosis of interrelationship between yield components and determine of direct and indirect effects of yield components on grain yield path analysis is necessary. Therefore, our objective was to apply path analysis for Evaluation relationships between yield and yield components in soybean grown under drought stress.

### MATERIALS AND METHODS

We conducted the experiment in the field conditions and without insect and disease stress at 34°23' N, 47°8' E; 1351 m elevation at Kermanshah, Iran at 2009. Eight cultivars of soybean (V<sub>1</sub>: Clark, V<sub>2</sub>: hobbit, V<sub>3</sub>: pershing, V<sub>4</sub>: Williams, V<sub>5</sub>: Goorgan-3 (registered name: Hood), V<sub>6</sub>: DPX, V<sub>7</sub>: M<sub>7</sub> and V<sub>8</sub>: M<sub>9</sub>) supplied by the oilseed company of the agricultural administration, Iran], that widely planted in Iran was selected as the experimental material. Soil samples were collected from experimental area at 0-30 cm depth. The results of soil analysis were shown in Table 1.

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**Table 1:** The results of soil analysis.

Soil properties	value
Soil texture	Silty clay
Organic matter (%)	2.2
pH	7.1
Electrical conductivity (dsm <sup>-1</sup> )	0.96
N (%)	0.15
P (ppm)	7.3
K (ppm)	515
Silt (%)	50.0
Sand (%)	8.6
Clay (%)	41.4

Two separate experiments (stress site and normal site) were performed based on randomized complete block design with three replications. Inoculation of seeds with appropriate strain of *Rhizobium japonicum* was carried out. In the normal site, irrigation was carried regularly when necessary to avoid water deficits, but in stress site, the plants were exposed to the drought stress by withholding irrigation at V<sub>4</sub>, R<sub>1</sub> and R<sub>3</sub> growth stages. Phonological stages were defined according to Fehr and Caviness (1977). At the end of growth season, ten plants were selected randomly from each plot then yield and yield components (number of node/plant, number of sub branch, number of pod/plant, number of seed/plant and 100-seed weight) was massured. To calculate final yield, two middle rows of each plot were completely harvested considering the sides. Weight 13% deduction of moisture, grain dry weight was calculated and considered as economic yield. Data for evaluated traits were statistically analyzed using a standard analysis of Variance technique based on randomized complete block design using the MSTATC software. Means were separated by the Duncan's Multiple Range Test at 5 percent probability level. Regression analysis and path analysis were conducted for both sites normal and stress by using SPSS software, separately.

## RESULTS AND DISCUSSION

The results were shown that there are significant differences in both sites (normal and stress) between cultivars concerning number of nod/plant, pod/plant, seed/plant and seed yield and 100-seed weight in stress site ( $P<0.01$ ), and number of sub branch in normal site ( $P<0.05$ ), which indicates the existence of genetic variations. Number of sub branch in stress site and 100-seed weight in normal site unaffected by cultivar effect (Table 1). Also, means comparison was shown that yield and yield components decrease in stress site compare with normal site, severely. Generally, Williams cultivars is better than the other cultivars and Hood is appeared weakness (Table 2). The results of simple correlation coefficients analysis in normal site (Table 3) indicated that correlation between yield and pod/plant ( $r=0.79^{**}$ ) and seed/plant ( $r=0.75^{**}$ ) lower than the correlation coefficients in stress site (Table 4) between yield and pod/plant ( $r=0.82^{**}$ ) and seed/plant ( $r=0.88^{**}$ ). Stepwise regression analysis for soybean yield was shown in Table 5. Association between grain yield and number of pod per plant was obtained through regression analysis stepwise method (Table 6). The results of stepwise regression analysis in normal site indicated that number of pod/plant as the first variable that entered in model and explaining 63 percent of total variations and recognized as the most effective role on grain yield (Table 7). Desclaux *et al.*, (2000) stated that water deficit reduced pod number per plant via decreases in flowering and increases in pod abscission. They emphasized that pod number is the most important yield component that injuring when that stress conditions occurred at early of plant flowering. The relationships between yield and yield components in normal site were shown in Fig 1. Based on figure 1, after pod/plant, the second factor that had higher effects on grain yield is number of seed per plant. Seed number was reduced by water stress at seed forming stage (Shamsi *et al.*, 2010; Kobraee and Shamsi, 2011c; Kobraee *et al.*, 2011d). Comparison of Fig 1 with Fig 2 and also the results of stepwise regression analysis (Table 8 and 9) are showing that in stress site seed/plant is the most important yield component that entered in model and explaining 77 percent of total yield variations. In addition, the best equations regression [Eq. (1 and 2)] in normal and stress conditions are showing the relationship between rate of yield components as the independed variable and the yield as a depended variable:

Eq. 1: Normal site

$$SY=1041.017-35.311NN-187.823NSS+85.083NPP+25.081NSP+31.111SWP \ (r^2=0.824)$$

Eq. 2: Stress site

$$SY=-420.267+0.398NN-77.790NSS+29.573NPP+46.035NSP+72.836SWP \ (r^2=0.790)$$

**Table 2:** Analysis of variance of yield and yield components of soybean in normal and stress sites.

Source of variation	df	MS											
		Number of node per plant		Number of sub branch		Number of pod per plant		Number of seed per plant		100-seed weight per plant		Seed yield	
		N	S	N	S	N	S	N	S	N	S	N	S
Block	2	1.39	1.16	0.01	0.16	3.57	0.38	2.86	0.50	0.09	0.03	13797.2	6717.5
Cultivar	7	47.30**	26.37**	0.64*	0.15 <sup>ns</sup>	72.92**	39.76**	173.37**	206.70**	1.03 <sup>ns</sup>	1.02**	822892.7**	954979.2**
Error	14	2.54	1.64	0.19	0.14	1.13	0.56	8.45	2.32	0.58	0.26	59803.9	29873.1
Coefficient of variation (%)	-	8.69	9.37	15.56	13.91	5.47	7.86	7.95	3.86	5.19	8.01	8.13	10.16

-ns, \* and \*\*: Non significant, significant at 5 and 1% levels of probability, respectively.

-N: normal condition S: stress condition

**Table 3:** Means comparison of yield and yield components of soybean in normal and stress sites.

Cultivar	Means											
	Number of node per plant		Number of sub branch		Number of pod per plant		Number of seed per plant		100-seed weight per plant (gr)		Seed yield (kg/ha)	
	N	S	N	S	N	S	N	S	N	S	N	S
Clark	21.2 b	14.1 b	3.5 a	2.4 a	20.4 c	11.3 bc	46.4 b	27.2 c	14.71ab	13.16 ab	2750 b	1435 cd
Hobbit	17.5 c	11.9 b	2.5 bc	1.7 a	19.1 cd	10.0 c	40.8 c	16.1 e	13.82 b	12.07 c	2712 b	1265 de
Pershing	17.5 c	13.9 b	2.3 c	1.9 a	15.9 e	10.2 c	37.6 c	19.2 d	14.75ab	12.73 bc	2873 b	1514 cd
Williams	26.3 a	17.4 a	3.1 abc	2.2 a	27.9 a	18.3 a	54.3 a	35.2 a	15.70 a	13.85 a	3611 a	2737 a
Hood	14.9 c	8.4 c	2.7 abc	2.1 a	12.3 f	5.1 d	29.6 d	10.1 f	13.98 b	12.03 c	2135 c	1046 e
DPX	21.5 b	17.6 a	3.3 ab	2.3 a	24.6 b	12.3 b	47.9 b	31.0 b	14.86ab	12.75 bc	3573 a	2356 b
M7	16.8 c	12.7 b	2.4 c	2.0 a	17.8 de	10.2 c	37.9 c	20.7 d	14.81ab	12.78 bc	3132 b	1723 c
M9	14.5 c	13.4 b	2.4 c	2.1 a	17.3 de	10.2 c	39.1 c	18.2 de	14.35ab	12.91abc	3086 b	1542 cd

-Similar letters in each column shows non-significant difference according to Duncan's Multiple Range Test at 5% level

-N: normal condition S: stress condition

**Table 4:** Correlation coefficient between yield and yield components in soybean in normal site.

	NN	NSS	NPP	NSP	SWP	SY
NN	1.00					
NSS	0.72**	1.00				
NPP	0.91**	0.52**	1.00			
NSP	0.92**	0.57**	0.93**	1.00		
SWP	0.65**	0.13 <sup>ns</sup>	0.51**	0.52**	1.00	
SY	0.62**	0.26 <sup>ns</sup>	0.79**	0.75**	0.46*	1.00

-ns, \* and \*\*: Non significant, significant at 5 and 1% levels of probability, respectively.

-NN: number of node per plant, NSS: number of sub branch, NPP: number of pod per plant, NSP: number of seed per plant and SWP: 100-seed weight per plant.

**Table 5:** Correlation coefficient between yield and yield components of soybean in stress site.

	NN	NSS	NPP	NSP	SWP	SY
NN	1.00					
NSS	0.11 <sup>ns</sup>	1.00				
NPP	0.81**	0.17 <sup>ns</sup>	1.00			
NSP	0.89**	0.32 <sup>ns</sup>	0.87**	1.00		
SWP	0.65**	0.10 <sup>ns</sup>	0.68**	-0.72**	1.00	
SY	0.79**	0.21 <sup>ns</sup>	0.82**	0.88**	0.69**	1.00

-ns, \* and \*\*: Non significant, significant at 5 and 1% levels of probability, respectively.

-NN: number of node per plant, NSS: number of sub branch, NPP: number of pod per plant, NSP: number of seed per plant and SWP: 100-seed weight per plant.

**Table 6:** Stepwise regression analysis ANOVA for soybean yield in normal site.

Model	df	Sum of squares	Mean square	F	Prob
Regression	5	4498093.6	899618.7	7.613	0.001
Residual	18	2127005.3	118166.9		
total	23	6625099.1			

-Predictors: (constant)

- Dependent variable: seed yield

**Table 7:** The results of stepwise regression analysis for soybean yield (as a dependent variable) in normal site.

Traits entered to model	Regression coefficient	Standard error	R <sup>2</sup>	T	Prob
Constant	1291.86	288.62	-	4.48	0.000
Number of pod per plant	88.47	14.45	0.63	6.12	0.000

-Predictors: (constant)

- Dependent variable: seed yield

**Table 8:** Path analysis for soybean yield in normal site.

	Direct effect	Indirect effect				
		NN	NSS	NPP	NSP	SWP
NN	-0.264 <sup>ns</sup>	-	-0.144	-0.224	-0.231	-0.146
NSS	-0.195 <sup>ns</sup>	-0.106	-	-0.101	-0.112	-0.024
NPP	0.763**	0.648	0.394	-	0.708	0.389
NSP	0.356*	0.312	0.205	0.330	-	0.186
SWP	0.048 <sup>ns</sup>	0.026	0.006	0.025	0.025	-
residual	0.566					

-ns, \* and \*\*: Non significant, significant at 5 and 1% levels of probability, respectively.

-NN: number of node per plant, NSS: number of sub branch, NPP: number of pod per plant, NSP: number of seed per plant and SWP: 100-seed weight per plant.

**Table 9:** Stepwise regression analysis ANOVA for soybean yield in stress site.

Model	df	Sum of squares	Mean square	F	Prob
Regression	1	5480552.1	5480552.1	73.70	0.000
Residual	22	1635961.1	74361.9		
total	23	7116513.3			

-Predictors: (constant)

- Dependent variable: seed yield

**Table 10:** The results of stepwise regression analysis for soybean yield in stress site.

Traits entered to model	Regression coefficient	Standard error	R <sup>2</sup>	T	Prob
Constant	348.88	166.98		2.09	0.048
Number of seed per plant	60.84	7.09	0.77	8.58	0.000

-Predictors: (constant)

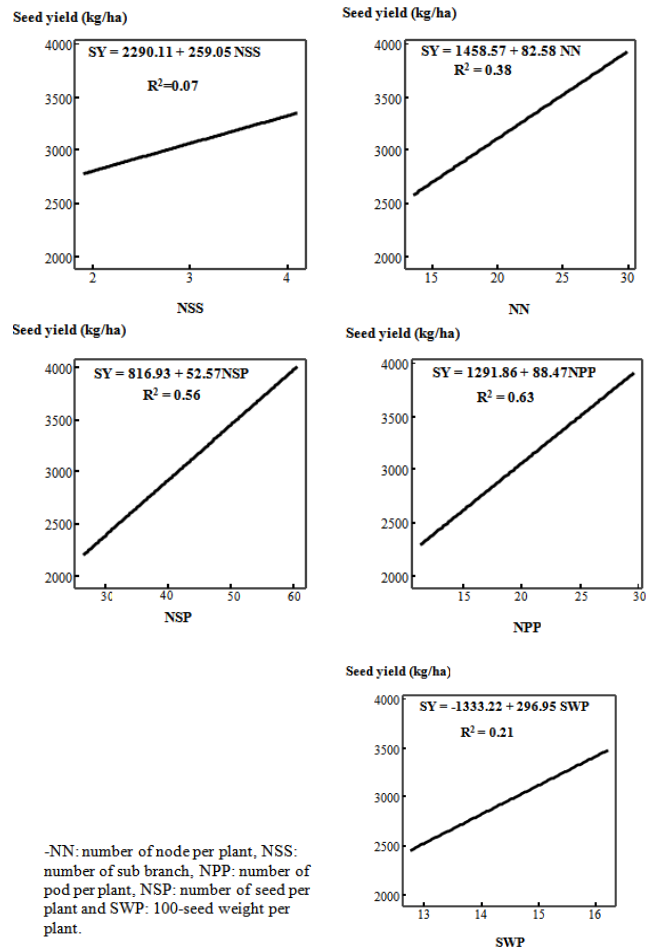
- Dependent variable: seed yield

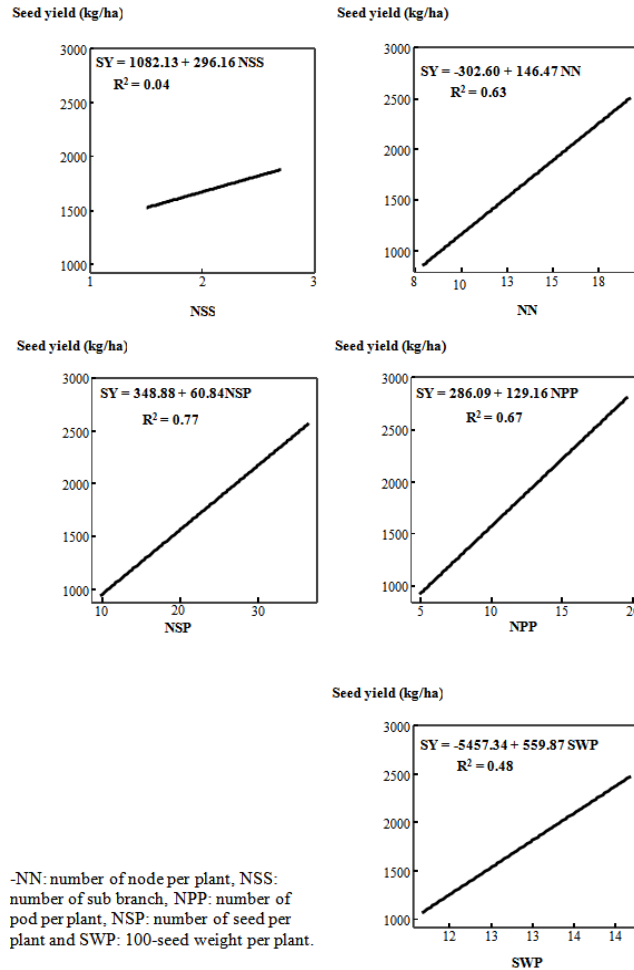
**Table 11:** Path analysis for soybean yield in stress site.

	Direct effect	Indirect effect				
		NN	NSS	NPP	NSP	SWP
NN	0.002 <sup>ns</sup>	-	0.017	0.016	0.017	0.013
NSS	-0.053 <sup>ns</sup>	-0.047	-	-0.042	-0.049	-0.030
NPP	0.188 <sup>ns</sup>	0.152	0.033	-	0.164	0.127
NSP	0.664 <sup>**</sup>	0.588	0.0214	0.579	-	0.479
SWP	0.090 <sup>ns</sup>	0.058	0.009	0.061	-0.065	-
residual	0.458					

-ns, \* and \*\*: Non significant, significant at 5 and 1% levels of probability, respectively.

-NN: number of node per plant, NSS: number of sub branch, NPP: number of pod per plant, NSP: number of seed per plant and SWP: 100-seed weight per plant.

**Fig. 1:** Relationships between yield and yield components in soybean in normal site.



**Fig. 1:** Relationships between yield and yield components in soybean in stress site.

Whereas SY is seed yield, and NN, NSS, NPP, NSP and SWP are the number of node per plant, number of sub branch, number of pod per plant, number of seed per plant and 100-seed weight per plant, respectively. These equations and Fig 1 and 2 are showing the role each of yield components in final yield together and separately. The method for the five components model explained most of the variation in yield with adjusted  $R^2$  values ranging from 0.790 to 0.824 (Eq. 1 and 2). The results of path analysis for normal and stress sites were shown in Table 7 and 10, respectively. In normal condition, direct effects on yield were greatest for number of pod per plant ( $0.763^{**}$ ), while, in stress site this value belonged to number of seed per plant ( $0.664^{**}$ ). In normal site, indirect effect of number of pod per plant on yield via the number of node per plant ( $0.648$ ) and number of seed per plant ( $0.708$ ) was greater than the other yield components. The results of path analysis for stress site (Table 10) indicated that indirect effect of number of seed per plant on yield via number of node per plant ( $0.588$ ), number of pod per plant ( $0.579$ ) and 100-seed weight ( $0.479$ ). Based on Akhter and Sneller, (1996) and Bali *et al.*, (2001) studies, evaluation of final yield and yield components for selection of high yielding cultivars is necessary and path analysis has been used to identify important yield components in soybean (Board *et al.*, 1999; Shukla *et al.*, 1999; Bali *et al.*, 2001). Number of node per plant in normal conditions had direct and negative effect ( $-0.264$ ) on soybean yield.

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