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Evaluation of the influence of plant population on yield and agro-morphological traits in soybean cultivars (*Glycine max* (L.) Merrill)

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Abstract

In order to investigate the effects of different densities on yield and yield components in soybean, an experiment was conducted in a factorial based on randomized complete block design with three replications at research farm, Islamic Azad University of Kermanshah at 2007-2008. Cultivars factor were placed in the blocks at 3 levels including M7, M9 , and Gorgan3 and density factors at 3 levels including plant were placed on 3,5,7cm intra rows spacing(53,32 and 23 plant.m^{-2}) in the blocks. The end of growth stage and harvesting time, the grain yield and yield components were determined. The results showed that density of 23 and 53 plant.m^{-2} had highest and lowest numbers of branches per plant , respectively. The highest number of node per plant and 100 grain weight per (main stem,branches and plant) related to M7 cultivar and highest number of pod per(branches and plant) related to Gorgan3 cultivar.also M7 and Gorgan3 had highest number of grain per plant and number of grain per branches , respectively. A significant correlation coefficient were found between grain yield with plant height(r=0.71**), number of grain per plant(r=0.73**), 100 grain weight(r=0.43**), biological yield (r=0.85**) and harvest index(r=0.34**). Gorgan3 had highest yield than two cultivars, M7 and M9. The highest yield related to density of 23 of plants.m^{-2}.

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Introduction

Soybean (*Glycine max* (L.) Merrill) is one of the important oilseed crops and major source of high quality protein for human daily diet and livestock feed in the world (Lei *et al.,* 2006). The annual worldwide production of soybean grain is approximately 250 M ton 101.4 M ha. Soybean is grown on an area of 115,000 ha with an annual production of 209,000 tones given an average yield of 1817 kg.ha^{-1} in Iran (FAO, 2008**)**. Among various agronomic factors limiting yield, planting pattern is considered of great importance. Bilal Ahmad *et al.,(* 2009)]stated that the optimum plant density with proper geometry of planting is dependent on variety, its growth habit and agro-climatic conditions. Parvez *et al.,* (1989) stated that plant height increased slightly with increase in planting density . Dhanjal *et al.*,(2001) reported that the highest plant height andnumber of grains per pod obtained using wide rowspacing. Previous work by Board *et al.*,(1992) showed that when row space and density were changed in a determinate year, pod number per plant was most influenced by this change. Leech *et al.*,(1998) reported that pods per branches were decreased with high plant density due to low micro climate space.According to Bing *et al.*,(2010) grain yield and numbers pod per plant were declined with increasing density.Liu *et al.*, (2008) stated that Adjusting planting density is an important tool to optimize crop growth and the time required for canopy closure, and to achieve maximum biomass and grain yield. Mohamadzadeh *et al.*,(2011) reported that the highest grain yield for 15, 30, 45 and 60 cm rows were obtained for narrow row of 30 cm.Ball *et al.*, (2000) reported that increasing plants population reduced yield of individual plants but increased yield per unit of area. Ismail & Hall, (2002)stated a decrease in grain yield of cowpea with increased spacing. .In addition, studies of Saxena and yadav (1975), Kambal(1986) and Coelho and Aguar(1989) showed that number of pod per plant decreased as plant spacing decreased, but yield per unit area was found to be increased. Ayaz *et al.*,(2001)stated that grains per pod changed with changing plant density and thickening density caused to reducing in grains per pod.Norsworthy and Shipe (2005) stated that the number of pods per plant and the number of seeds per plant compensated for low plant densities.Nakano *et al.*,(2001) also reported that planting pattern affected the light environment within the canopy, which determined the branch node number, pod number and seed yield. Jason and Emerson (2005) reported that low plant densities in soybean may result in an increase in the number of lateral branches and in a greater contribution of these lateral branches to the total yield.according toWells *et al.*, (1993) radiation penetrating in to canopy was decreased with high plant density and reduced branches number. The objective of this work was mainly to investigate the response of yield and quantitative characteristics of soybean crop to sowing density.

Materials and methods

Experimental design and treatments

A field experiment was conducted as factorial based on Randomized Complete Block with three replicates in 27 plots at Agricultural Research field of Islamic Azad University of Kermanshah,Iran. Soybean cultivars M7, M9 , and Gorgan3 were sown manually in 53(*3cm intra rows spacing)*, 32 (*5cm intra rows spacing)* and 23(*7cm intra rows spacing)* plants.m-^{2} at the May 15. The plots consisted of four rows, 4 m in length spacing 60 cm apart.

*Soil analysis*In order to do the soil analysis at the field condition, soil samples were collected from experimental area at 0-30 cm depth.the soil texture of the study area was silty-clay with a pH of 7.5, total organic matter 2.2%, electrical conductivity (ECe) 0.63dsm^{-1}. before planting of soybean, fertilizers were used as follows : 200 kg P2O5/ha and 50 kg N/ha and mixed with soil and land was ploughed once and harrowed twice. Inoculation of seeds with appropriate strain of

Rhizobium japonicum was carried out.*Control of diseases and pests*

Diseases and pests were controlled by regular applications of fungicides and Insecticides.

Plant sampling and measuring

At the end of growth season, Ten randomly sampled plants were taken from the central rows of each plot and measured yield attributes and morphological characteristics.The weight of 100 seeds was recorded as the average of three 100-seed samples. Two central rows were harvested for measuring seed yield. Also, to determine biological yield, whole plant dry weight was considered as biological yield. And to determine harvest index, the ratio of seed weight to total plant biomass, was calculated as total dry seed weight divided by total above ground dry biomass per plant (Denier van der Gon *et al*., 2002).

Statistical analysis

Statistical MSTATC software was used to analyze data and Duncan Test software was applied to compare means of data (p<5%).

Results and discussion

Plant height

The effects of density and cultivar on plants height was highly significant (P < 0.01). The most elevated height of plant was allotted to cultivar Gorgan3 and density of 23 plant.m^{-2}. Density of 23 plant.m^{-2}caused the highest plant height and density of 53plant.m^{-2}caused the lowest. Enyi ,(1973) stated that plant height increased with increasing plant density and nodule number on stem reduced also, (Boquet1990 ,Pedersen and Lauer 2003) report is in agreement with findings of this research .

Table 1. Analysis of variance of yeild and yeild components of soybean.

		MS								
Source of variation	d.f	PH	NBP	NNP	NPP	NGP	WGP	GY	BY	HI
Replication	2	968.17	0.514	171.329	173.456	893.730	0.263	435525.227	3135071.882	11.980
Cultivar	2	68.854ns	6.463**	150.185**	342.099**	1235.597**	12.339**	2339605.738**	2743127.667**	62.357**
Density	2	592.134**	11.769**	458.467**	1006.249**	1492.161**	ns1.125	4806266.070**	7204368.263**	ns162.338
Cultivar × Density	4	ns43.322	ns0.233	ns30.340	ns64.984	ns120.458	ns0.279	ns330646.292	ns1255418.210	ns32.685
Error	16	48.419	0.528	23.520	62.498	145.595	0.093	1599322.813	8860195.656	6.234
Coefficient of variation	-	8.67	26.20	12.81	16.73	13	8.85	9.35	23.17	6.42

Ns, * and **: Non significant, significant at 5 and 1% levels of probability, respectively. PH: Plant height , NBP: number of branches per plant, NNP: number of node per plant, NPP: number of pod per plant, NGP: number of grain per plant, WGP: 100grain weight, GY: grain yield, BY: biological yield, and HI: harvest index.

Number of branches per plant

The effect of cultivar on number of branches per plant was significant and M9 had the highest number followed by M7 and Gorgan3. Since reduced branching at high plant populations has been reported (Weber *et al*., 1966; Blumenthal *et al*., 2005; Das *et al*., 1996).

Number of pod per(plant ,branches and main stem)

The highest and lowest pod per plant pertained to the density of 23 and 53 plant.m^{-2}, respectively. Number of pods per plant was significantly higher for M9 and Gorgan3 than that of cultivar M7. Statistical analysis showed that , number of pod per plant and number of pod per branches were highly significantly and significantly influenced by cultivar,respectively.also number of pod per (plant , branches and main stem) were highly significantly influenced by density. Comparison of means was showed that highest number of pod per main stem related to M7 but, the highest number of pod per(branches and plant) related to Gorgan3. According to Boquet,(1990) and Bing *et al*., (2010) grain yield and numbers pod per plant were declined with increasing density. The results this experiment are in line with those of Abbas *et al*.,(1994) and Ikeda, who had also recorded more number of pods per plant at lower density.

Table 2. Means Comparison of yield and yield components of soybean.

Traits	PH (cm)	NBP	NNP	NPP	NGP	WGP (g)	GY(kg.h^{-1})	BY(kg.h^{-1})	HI (%)
Cultivar									
C1	82.94A	2.85A	39.71A	50.73A	95.92A	17.30A	3663A	6257C	41/91A
C2	77.42A	1.89B	33.19B	40.13B	79.83B	15.19B	2797B	7230B	37.33B
C3	80.47A	3.58A	40.71A	50.89A	102.60A	17.17B	3689A	8196A	37.38B
Density									
D1	89.40A	1.76C	31.07C	58.63A	79.19B	16.63B	3971A	9912A	33.97B
D2	77.56B	2.55C	37.24AB	45.39B	94.41A	16.94A	3437A	7899B	40.32A
D3	73.88B	4.01A	45.30A	37.73B	104.80A	16.31B	2842B	6599C	41.33A
Cultivar × Density									
C1D1	96.40A	1.76DE	31.10BC	36.20C	76.03DE	17.10B	4197A	4233A	35.74CD
C1D2	79.30BC	2.60CD	39.60B	49.40BC	96.50ABCD	17.87A	3545A	8006A	41.85B
C1D3	73.13BC	4.20AB	48.43A	67.07A	115.20A	16.93B	3325A	6533A	48.15A
C2D1	86.23AB	1.03E	26.63C	34.50C	70.23E	15.33C	3242A	9247A	33.63D
C2D2	73.87BC	1.86CDE	35.43BC	38.73C	83.60CDE	15.33C	2961A	6661A	42.27B
C2D3	72.17BC	2.76CD	37.50B	47.17BC	85.67CDE	14.90C	2188A	5780A	36.08CD
C3D1	85.57 ABC	2.46CD	35.47BC	42.50BC	91.30BCDE	16.63B	4174A	5074A	32.53D
C3D2	79.50BC	3.20BC	36.70B	48.03BC	103.10ABC	17.63A	3805A	9031A	39.84BC
C3D3	76.33BC	5.06A	49.97A	61.67AB	113/50AB	17.10B	3011A	7772A	39.77BC

In each column with similar letter(s) are not significantly different at the 5% level of probability (DMRT) C, D and C×D:cultivar, planting density and cultivar × planting density, respectively.C1:M7,C2:M9,C3:Gorgan3 Cultivars &D1: 23,D2: 32, D3: 53plant.m^{-2}. PH: plant height, NBP: number of branches per plant, NNP: number of node per plant, NPP:number of pod per plant, NGP:number of grain per plant,WGP: 100grain weight, ,GY: grain yield BY: biological yield, and HI: harvest index.

Table 3. Analysis of variance some of quantitative characteristics of soybean.

		MS							
Source of variation	d.f	NNMS	NNB	NPMS	NPB	NGMS	NGB	WGMS	WGB
Replication	2	4.805	95.414	40.047	179.607	393.363	233.655	0.256	0.096
Cultivar	2	*2.029	**183.968	^{ns}13.539	**534.583	*223.800	**692.038	*15.794	^{ns}10.650
Density	2	**28.638	**718.101	**123.614	**1067.895	^{ns}4.367	**1061.169	^{ns}1.938	^{ns}0.263
Cultivar × Density	4	^{ns}1.661	^{ns}22.746	^{ns}6.038	^{ns}137.632	^{ns}31.601	^{ns}84.590	^{ns}.0.295	^{ns}0.437
Error	16	1/414	23.144	11.773	80.322	43.044	100.413	0.246	^{ns}0.156
Coefficient of variation	-	6.15	26.81	12.10	22.74	10.85	26.97	7.97	7.39

Ns, * and **: Non significant, significant at 5 and 1% levels of probability, respectively. NNMS: number of node per main stem,NNB: number of node per branch, NPMS: number of pod per main stem, NPB: number of pod per branch, NGMS: number of grain per main stem, NGB: number of grain per branch,WGMS: 100grain weight per main stem, WGB: 100grain weight per branch.

Number of grain per(plant ,branches and main stem)

In this study was observed that effects of density and cultivar on the number of grain per plant were highly significant. Number of grain per (plant and branches) and number of grain per main stem were highly significantly and significantly influenced by cultivar,respectively.also, number of grain per (plant and branches) were highly significantly influenced by density. Comparison of means was showed that highest number of grain per branches related to M7 but, the highest number of grain per(main stem and plant) related to Gorgan3.These results correspond to those of Boquet,(1990);Wahab *et al.* (1986).

100 grains weight

The weight of 100 grains of soybean was highly/ significantly affected by cultivar.the maximum weight of 100 grains pertained to the Gorgan3 and there was no significant difference between M7 and M9 in this

regard. Taha.,(1988) ; Shirtliffe & Johnston(2002) reported that 100 grain weight was not affected by plant spacing.Ziska and Hall (1983) stated that grain weight is negatively correlated with the number of seed per plant.

Table 4. Means Comparison some of quantitative characteristics of soybean.

Traits	NNMS	NNB	NPMS	NPB	NGMS	NGB	WGMS(g)	WGB(g)
Cultivar								
C1	21.59A	19.96A	29.78A	23.77A	58.38B	42.90A	17.47A	17.32A
C2	18.94B	12.77B	27.60A	12.26B	58.38B	27.06A	15.17B	15.28B
C3	19.44A	21.11A	27.71A	26.89A	66.17A	41.49A	17.46A	16.94A
Density								
D1	21.13A	9.82C	32.03A	32.03A	9.91C	24.97B	16.52B	16.34A
D2	19.28B	16.50B	28.43B	28.43B	21.31B	40.67A	17.22A	16.67A
D3	17.57C	27.51A	24.62C	24.62C	31.69A	45.81A	16.34B	16.53A
Cultivar × Density								
C1D1	21.33AB	9.73CD	33.70A	33.70A	9.30C	26.67CD	17.17B	17.03AB
C1D2	20.20ABCD	19.23B	30.80ABC	30.80ABC	20.53BC	45ABC	18.07A	17.67A
C1D3	17.23E	30.90A	24.83CD	24.83CD	41.47A	57.03A	17.17B	17.27A
C2D1	20.47ABC	6.00D	30.67ABC	30.67ABC	7.73C	15.77D	15.40CD	15.57C
C2D2	18.30CDE	13.03BCD	28.40ABCD	28.40ABCD	12.93C	34.87BC	15.50C	15.07C
C2D3	18.07DE	19.27B	23.73D	23.73D	16.10BC	30.53BCD	14.60D	15.20C
C3D1	21.60A	13.73BCD	31.73AB	31.73AB	12.70C	32.47BCD	17.00B	16.43B
C3D2	19.33BCDE	17.23BC	26.10BCD	26.10BCD	30.47AB	42.13ABC	18.10A	12.27A
C3D3	17.40E	22.37A	25.30BCD	25.30BCD	37.50A	49.87AB	17.27AB	17.13AB

In each column with similar letter(s) are not significantly different at the 5% level of probability (DMRT) C, D and C×D:cultivar,planting density and cultivar × planting density,respectively.C1:M7,C2:M9,C3:Gorgan3 Cultivars&D1:23,D2: 32, D3: 53plant.m^{-2}.NNMS:number of node per main stem,NNB:number of node per branch,NPMS:number of pod per main stem, NPB:number of pod per branch, NGMS:number of grain per main stem,NGB:number of grain per branch,WGMS:100grain weight per main stem,WGMS:100grain weight per branch.

Grain yield

In the present research, effects of density and cultivar on grain yield were highly significant.The highest and lowest grain yield pertained to the density of 23 and 53 plant.m^{-2}, respectively. There was no significant difference between 32 and 23 plant.m^{-2}, in this regard. Also, the highest and lowest grain yield pertained to the cultivars of Gorgan3and M9, respectively. Larry *et al*.,(2002) indicated that grain yield was reduced with decreasing plant density. Boquet,(1990) revealed that grain and pod number per plant are typically reduced by increasing plant population, but this reduction is more than offset by the greater number of plants per square meter up to some optimum plant population.Ball *et al*.,(2000) observed similar results and concluded that increasing plants population reduced yield of individual plants but increased yield per unit of area. Similar findings have also been reported in other research (Asanome & Ikeda, 1998, Bowers et al.,2000,Acikgoz *et al*., 2009).

Biological yield

The density had a highly significant effect on biological yield. The density 23 plant.m^{-2} had the highest biological yield and 53 plant.m^{-2} had the lowest. The effect of cultivar on biological yield was highly significant. Gorgan3 had the highest biological yield and M9 had lowest.

Harvest index

Harvest index was significantly affected by cultivar .The maximum and minimum harvest indexes pertained to the Gorgan3 and M7, respectively. There

was no significant difference between M9 and M7, in this regard. Weber *et al.*, (1966) revealed that that very high populations in some crops, including soybean, may decrease HI because of lodging or barren plants. Crothers and Westerman,(1976) indicated that harvest index was reduced with increasing plant density.In additional, Non-significant effect of spacing on harvest index of legumes has also been reported by Sharar *et al.*, (2001) and Hussain *et al.* (1998) (Table 1, 2, 3 & 4).

Table 5. Correlation coefficient between yield and quantitative characteristics of soybean.

Traits	PH	NBP	NNMS	NNB	NNP	NPMS	NPB	NPP	NGMS	NGB	NGP	WGMS	WGB	WGP	GY	BY	H	I
PH	1																	
NBP	.243-	1																
NNMS	.531**	*.451-	1															
NNB	.334-	.878**	.375-	1														
NNP	.220-	.813**	.244-	.962**	1													
NPMS	.598**	.332	.577**	.425-*	.277-	1												
NPB	.386-*	.797**	.358-	.778**	.747**	.429*	1											
NPP	.280-	.797**	.395-*	.827**	.822**	.173-	.861**	1										
NGMS	.456*	.234	.287	.082	.137	.236	.150	.208	1									
NGB	.191-	.691**	.269-	.746**	.764**	.201-	.854**	.854**	.233	1								
NGP	.054	.773**	.245-	.686**	.715**	.059-	.755**	.856**	.559**	.882**	1							
WGMS	.395*	.262	.258	.130	.177	.142	.232	.211	.938**	.276	.550**	1						
WGB	.137-	.754**	.249-	.772**	.780**	.184-	.856**	.859**	.222	.975**	.870**	.278	1					
WGP	.079	.705**	.077-	.651**	.674**	.078-	.766**	.758**	.613**	.872**	.923**	.678**	.892**	1				
GY	.718**	.112-	.560	.230-	.140-	.526**	.020-	.81-	.299	.070	.731**	.394*	.095	.255	1			
BY	.526**	.088-	.054-**	.042	.035	.223-	.138	.032	.036	.041-	.084	.024	.034-	.008	.855**	1		
HI	.344**	.400*	**.514-	.488**	.493**	.292-	.560**	.543**	.048-	.656**	.546**	.003	.603**	.455*	.711*	.143	1	

Ns, * and **: Non significant, significant at 5 and 1% levels of probability, respectively. PH: plant height, NBP: number of branches per plant, NNMS:number of node per main stem,NNB:number of node per branch,NNP: number of node per plant, ,NPMS:number of pod per main stem, NPB:number of pod per branch, NPP:number of pod per plant, NGMS:number of grain per main stem, NGB :number of grain per branch, NGP:number of grain per plant, WGMS:100grain weight per main stem ,WGB:100grain weight per branch, WGP: 100grain weight per plant, ,GY: grain yield BY: biological yield, and HI: harvest index.

Correlation coefficients

Correlation coefficients for grain yield and other traits of cultivars of soybean are shown in Table 5. Highly positive correlation coefficients of number of pod per plant with number of branches (r=0.79**) was observed. A highly significant correlation coefficient were found between number of grain per plant with number of branches(r=0.77**),number of pod per plant(r=0.85**),number of grain per main stem (r=0.55**) and number of grain per

branches(r=0.88**) also, found strong positive Correlations between grain yield with plant height(r=0.71**),number of grain per plant(r=0.73**),100 grain weight(r=0.43**),biological yield(r=0.85**) and harvest index(r=0.34**).A highly significant correlation coefficient were found between biological yield with grain yield (r=0.82**),plant height(r=0.52**), length of internode(r=0.53**) and 100 grain weight(r=0.57**) were observed. Significant positive correlations were also found between harvest index with grain yield(r=0.71**),dry grain weight per plant (r=0.45**),number of grain per plant(r=0.54**) and number of pod per plant(r=0.54**). These results are in agreement with other reports by Akhter and Sneller (1996) ; Board *et al.* (1997) ;Nakawuka and Adipala, 1999; Iqbal *et al.,* 2003 ; Malik and Ashraf, (2006) and Arshad *et al.,* 2006 .

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