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Response of soybean yield to manganese foliar application under short-term drought stress

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Abstract

This research was done in order to investigate the Response of soybean yield to manganese foliar application under short-term drought stress at flowering stage in climatic condition of Kermanshah, Iran 2010. The experimental design was a split split plot based on Randomized Complete Block design with three replicates. Treatments includes: two irrigation regimes, two foliar treatments, and eight soybean cultivars. At the V4 growth stage, the plants were sprayed twice with 0.5% manganese liquid or distilled water. At the end of growing season, biological yield, grain yield, yield components and harvest index were measured. The results of analysis variance were shown that irrigation regimes, manganese foliar treatments and cultivars had significant effects on number of pod and seed per plant, grain yield and biological yield at 1% level ($P<0.01$). Irrigation at all of growth stages and manganese foliar application produced the highest number of node per plant, number of sub branch, number of pod and seed per plant, grain yield and biological yield in soybean cultivars. Whereas, maximum 100-seed weight and harvest index were obtained with irrigation withholding at flowering stage. The effect of Mn foliar application in water deficit condition on pod and seed number, grain yield, and biological yield were higher than when manganese was used in I_c treatment.

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Introduction

Soybean growth and yield depends on the availability of mineral nutrients. Among vital elements, manganese is particular importance, because manganese has an important role in chlorophyll and carotenoids synthesis, improves plants photosynthesis, growth and yield. Vegetative growth reduction, decrease in flower and pod, and infertility of pollen particles are Symptoms of manganese deficiency. Manganese is involved in photosynthetic and respiratory enzymes synthesis and prevents from nitrate accumulation in tissues plant (Ziaeian and Malakoti, 1998); because manganese is identified a cofactor for nitrogen catabolism in leaves (Izauirre-Mayoral and Sinclair, 2005). Availability of manganese for plant uptake is affected by soil pH, it decreases as the pH increases (Bromfield *et al.,* 1983). Also, under drought stress, plant roots cannot absorb micronutrients (Heidarian *et al.*, 2011) such as manganese, and foliar spraying of manganese is useful and more influential as compared to soil application (Narimani *et al.*, 2010). Soybean is considered a sensitive the several abiotic stress (Van Heerden and Kruger, 2000) such as drought (Lobato *et al.*, 2008) and manganese deficiency (Barker and Pilbeam, 2007). Averagely, soybeans use about 450–700 mm of water during the growing season (Dogan et al. 2007). Growth and yield of soybean was reduced by water deficit (Korte *et al.*, 1983) and these effects are influenced by the timing and severity of the stress (Desclaux *et al.*, 2000). Although many studies show that the application of Mn at water deficit conditions can have different results in terms of yield response (Ronaghi and Ghasemi-Fasaei, 2008; Babaeian *et al.*, 2011; Jabeen and Ahmad, 2011; Yousefi, 2012) but, Vadez et al., (2000) suggested that Mn could be particularly important in the case of soybean grown in soil with low Mn availability and exposed to water deficit. Therefore, the objective of this work was to test the hypothesis that manganese foliar application would improves yield and yield components of soybean when that short period of drought stress occurred at flowering stage.

Materials and methods

Site description and soil analysis

The experiment was carried out in 2010 at the Research Field of the Faculty of Agriculture, Islamic Azad University of Kermanshah, Iran (34°23' N, 47°8' E; 1351 m elevation). Before planting, soil samples were collected from experimental area at 0-30 cm depth. The results of soil analysis were shown in Table 1.

Table 1. The results of soil test.

Soil properties	value
Soil texture.........................	Silty clay
Silt (%)	49.1
Clay (%)	42.4
Sand (%)...........................	8.5
Organic matter (%)	2.6
pH	7.3
Electrical conductivity (dsm^{-1})...	0.83
N (%)	0.11
P (ppm)	8.2
K (ppm)	531
zinc (mg/kg)	0.81
Iron (mg/kg)	2.76
Manganese (mg/kg)	4.49

Treatments and experimental design

Treatments includes: two irrigation regimes: (I1) Irrigation at all of growth stages, (I2) Irrigation Withholding at flowering stage. There were two foliar treatments which consisted: (Mn0) spray with distilled water, (Mn1) manganese spray, and eight soybean cultivars includes: Clark (V1), Williams (V2), Sahar or Pershing (V3), Hobbit (V4), Gorgan 3 (V5), M7 (V6), M9 (V7), and DPX (V8). The experimental design was a split split plot based on Randomized Complete Block design with three replicates. The quantity of irrigation water in each plot was calculated according to Karam *et al.*, (2005), controlled by counter and exercise irrigation treatment at flowering stage. At the V4 growth stage (based on Fehr and Caviness, 1977), the plants were sprayed twice (with one week interval) with 0.5% manganese liquid or distilled water until the leaves were wet. Before planting of soybean, fertilizers were used as follows: 24 kg P_2O_5 and 5.5 kg N and mixed with soil and land was ploughed once and harrowed twice. All seeds were inoculation with *Bradyrhizobium japonicum* immediately before sowing. Each plot was 6 m in length, 240 cm in Width, 60 cm in row spacing, and with density of 33 plants/m^2.

Plant sampling

At the end of growing season, measurement of examined characters was done on plants which had been randomly chosen in the mid-row of each plot. The following measurement and were made: number of node per plant, number of sub branch, number of pod per plant, number of seed per plant, 100-seed weight, grain yield, biological yield, and harvest index. 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 grain yield. To determine biological yield, total plant dry weight was employed as biological yield. The harvest index at maturity was calculated from the ratio of grain dry weight to total above ground plants dry weight.

Statistical analysis

Data for evaluated traits were statistically analyzed using a standard analysis of Variance technique using the MSTATC software. Means were separated by the Least Significance Difference Test (LSD) at 5 percent probability level.

Results and discussion

The results of this study revealed that irrigation regimes, manganese foliar treatments and cultivars had significant effects on pod $plant^{-1}$, seed $plant^{-1}$, grain yield and biological yield of soybean at 1% level ($P<0.01$). Also, analysis variance showed that number of sub branch in soybean affected by irrigation regimes at 5% level ($P<0.05$), while, was not affected by manganese foliar treatments and cultivars. Irrigation regimes and manganese foliar treatments had no effects on number of node per plant, 100-seed weight and harvest index in soybean plants (Table2). These results are parallel to (De Costa *et al.*, 1999; Al-Suhaiban, 2009; Singh *et al.*, 2008). Samarah *et al.*, (2004) reported that drought stress decreases roots growth, nutrient mobility in soil and nutrient uptake from the soil to roots and and because plant growth is reduced. Irrigation at all of growth stages and manganese foliar application produced the highest number of node per plant, number of sub branch, number of pod and seed per plant, grain yield and biological yield in soybean cultivars (Fig 1). Whereas, maximum 100-seed weight and harvest index were obtained with irrigation withholding at flowering stage (Fig1). In Samarah *et al.*, (2004) study the highest 100-seed weight in soybean was obtained at non irrigation treatment. Manganese foliar application increases 100-seed weight (14.09 in Mn1 compared 13.96 in Mn0), but on the other hand, decreases harvest index in soybean plants (Fig1). It is important to note that the impressionable of evaluated traits from the irrigation regimes was more than manganese application. For example, with irrigation complete (I_c) the grain yield of soybean increased by 62.7% compared with check treatment (I_w) (2512.7 $kg.ha^{-1}$ compared 1544.3 $kg.ha^{-1}$), whereas, 12% added to grain yield with Mn application (2151.8 in Mn1 compared 1905.2 in Mn0). The similar results were observed in number of pod and seed per plant and biological yield (Fig1). Crabtree, (1999) and Hebbern *et al.*, (2005) emphasized that manganese application increases yield and yield components in different crops. In this experiment, increase in seed weight with withholding irrigation at flowering stage (I_w) was expected, because, drought stress at flowering stage Increases aborted flowers and decrease in the number of seed per plant is associated with increase in seed weight. These results were different with results obtained by Kumaga *et al.*, (2003) that reported in groundnut, water stress led to more pods and seeds and lower seed weight. On the other hand, drought stress reduced pollen fertility, flower formation, and pod set in soybean (Sepaskhah, 1977) and groundnut (Elia and Mwandemele, 1986). The irrigation regimes × manganese foliar treatments interaction significantly ($P<0.01$) was influenced the pod $plant^{-1}$, seed $plant^{-1}$, grain yield and biological yield, and had no effect on other traits. Except number of pod per plant and biological yield, other evaluated traits not affected by irrigation regimes × cultivars interaction. In addition, manganese foliar treatments × cultivar interaction, only affected biological yield at 5% level ($P<0.05$). Irrigation regimes × manganese foliar treatments × cultivars interaction had significantly effects on biological yield ($P<0.01$), and pod plant^{-1}, seed plant^{-1}, and grain yield ($P<0.05$) (Table2).

Table 2. The results of analysis variance of soybean yield affected by manganese foliar application under drought stress.

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	Grain yield	Biological yield	Harvest index
Replication	2	0.01	0.03	18.91	18.61	0.06	8298.76	8192.01	17.11
Irrigation (A)	1	0.03^{ns}	3.60*	4510.04**	10546.23**	0.45^{ns}	22512782.51**	150695805.04**	7.76^{ns}
Error (a)	2	0.13	0.05	18.00	0.06	0.09	26159.19	1860.51	6.30
Mn foliar (B)	1	4.90^{ns}	0.37^{ns}	188.72**	904.05**	0.37^{ns}	1460513.34**	12009105.37**	14.18^{ns}
(A)×(B)	1	0.17^{ns}	0.24^{ns}	124.67**	241.93**	0.01^{ns}	95319.01*	611523.37**	3.96^{ns}
Error (b)	4	1.41	0.08	4.58	0.54	0.69	10297.89	23523.53	3.88
Cultivar (C)	7	8.28*	0.09^{ns}	153.73**	232.59**	0.92^{ns}	518187.20**	2868205.45**	2.31^{ns}
(A)×(C)	7	1.38^{ns}	0.07^{ns}	19.08**	15.11^{ns}	0.16^{ns}	32207.27^{ns}	422829.59**	2.01^{ns}
(B)×(C)	7	3.18^{ns}	0.01^{ns}	8.71^{ns}	16.78^{ns}	0.05^{ns}	30757.72^{ns}	116439.54*	2.19^{ns}
(A)×(B)×(C)	7	2.34^{ns}	0.04^{ns}	14.75*	27.58*	0.12^{ns}	41634.06*	428722.11**	2.77^{ns}
Error (C)	56	2.98	0.13	5.10	11.73	0.99	17476.46	45990.79	4.36
Coefficient of variation (%)	-	8.92	13.62	6.29	7.62	7.10	9.52	10.96	6.31

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

The interaction effect of irrigation regimes and manganese foliar application on yield and yield components of soybean were shown in Fig (2). Based on the results obtained, in irrigation complete condition, manganese spray had a little effect on number of node, pod and seed per plant. The effect of Mn foliar application in water deficit condition on pod and seed number, grain yield, and biological yield were higher than when manganese was used in I_c treatment. Sarkar *et al.*, (2007) and Cakmak, (2008) stated that foliar application of elements in drought stress condition is better than the soil application, because at this condition nutrient deficiency cannot be corrected by soil application. Manganese foliar application at irrigation at all of growth stage condition increase pod and seed number, grain yield, and biological yield by 19%, 31.3%, 22.3%, and 23.2%, respectively. In contrast, the highest harvest index (40.22%) was obtained in I_wMn0 treatment (Fig2). Lewis and McFarlane, (1986) reported that yield of safflower has increased by 40% by manganese foliar application. At this experiment conditions, comparison of evaluated soybean cultivars (Fig3) showed that the maximum number of node per plant, number of sub branch, number of pod and seed per plant, grain yield, and biological yield belonged to Williams cultivar. In the other side, Clark and M9 had the highest 100-seed weight and harvest index, respectively.

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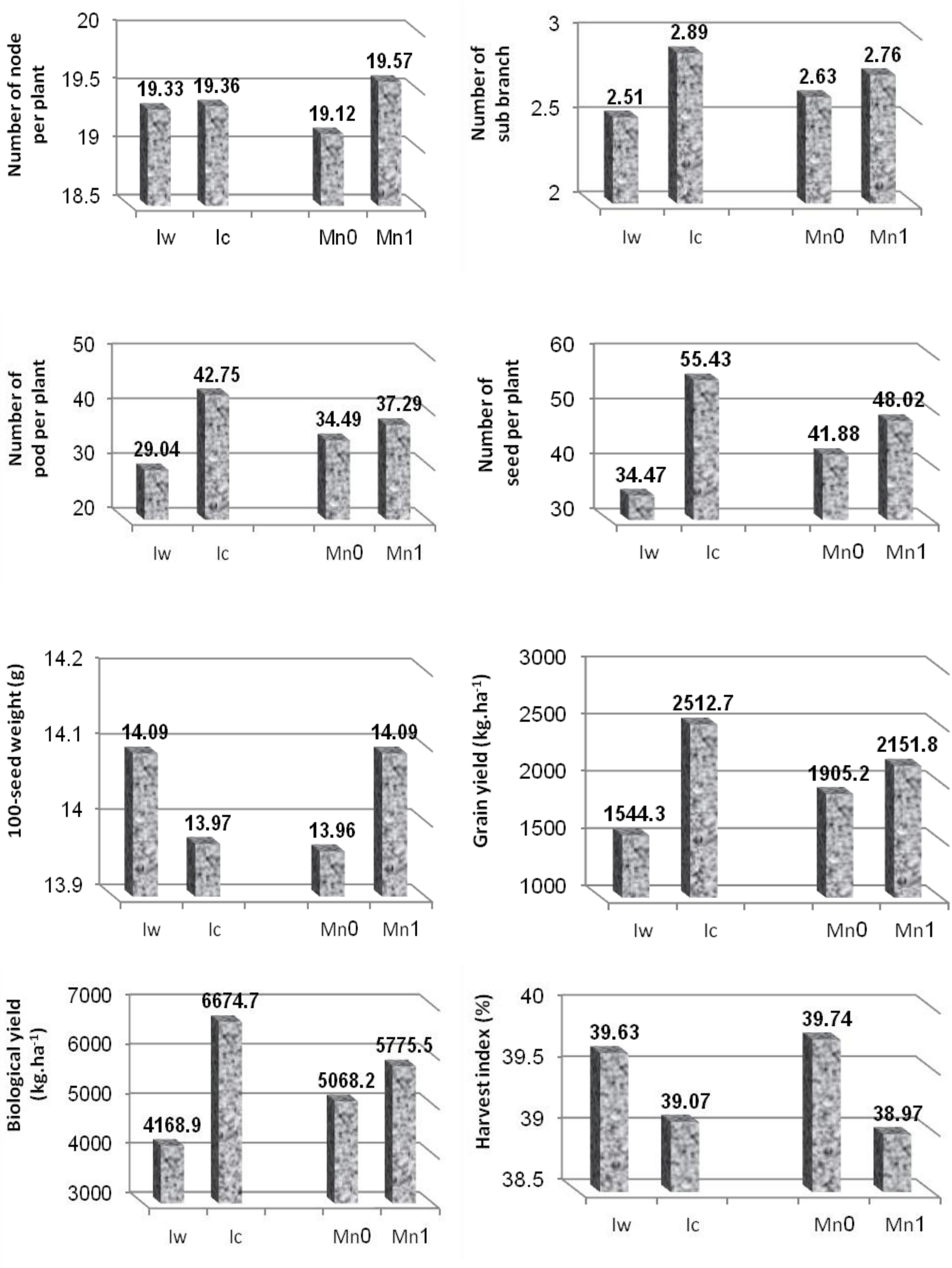

Fig. 1. The effects of irrigation regimes and manganese foliar treatments on yield and yield components of soybean.

I_c: irrigation at all of growth stages, and I_w: withholding irrigation at flowering growth stage.

Mn_0: spray with distilled water, and Mn_1: manganese spray.

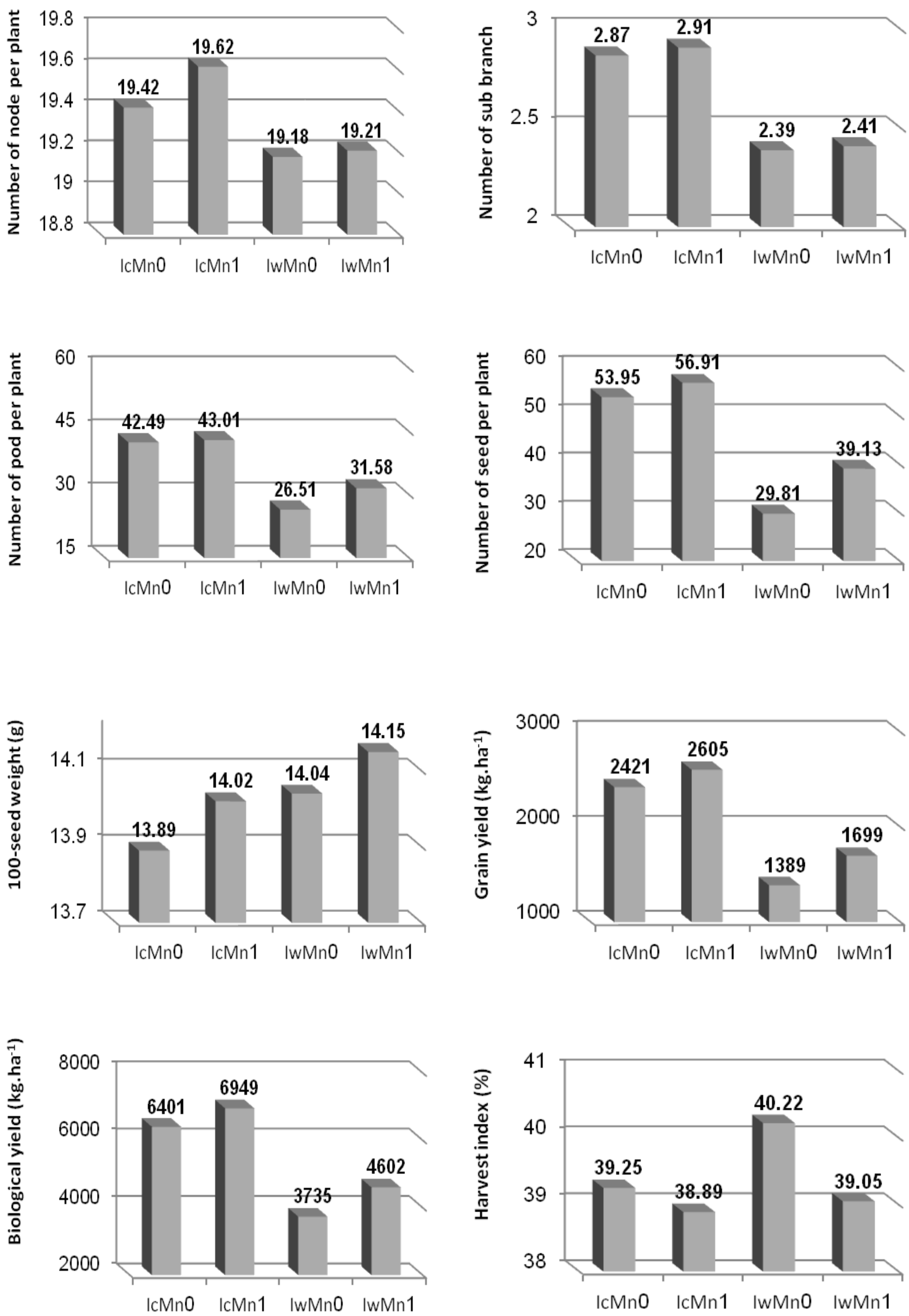

Fig. 2. Interaction effects of irrigation regimes and manganese foliar treatments on yield and yield components of soybean.

I_c: irrigation at all of growth stages, and I_w: withholding irrigation at flowering growth stage.

Mn_0: spray with distilled water, and Mn_1: manganese spray.

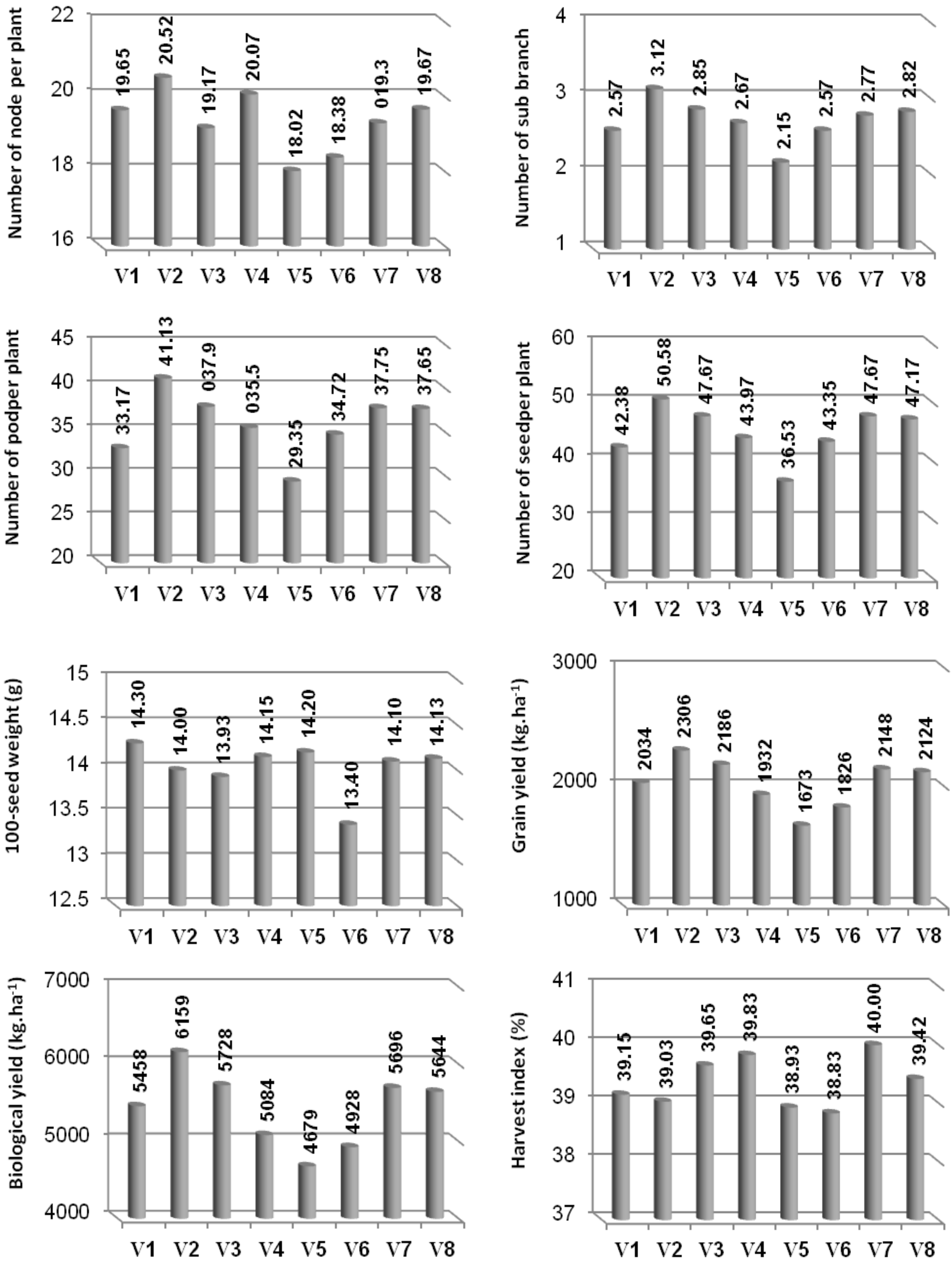

Fig. 3. Yield and yield components of soybean cultivars at experimental conditions.
V1: Clark, V2: Williams, V3: Pershing, V4: Hobbit, V5: Gorgan3, V6: M7, V7: M9, V8: DPX.

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