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YIELD AND YIELD ATTRIBUTES AS INFLUENCES OF SOYBEAN (*GLYCINE MAX* L.) AND IRRIGATION REGIMES

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ABSTRACT
The research was conducted in the Agronomy Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the Rabi season. The experiment consists of two factors: factor A. V_1= Binasoybean-1, V_2= Binasoybean-2, V_3= Binasoybean-3, V_4= Binasoybean-4. Factor B. Irrigation: I_0 = Rainfed (No Irrigation), I_1 = One Irrigation, I_2 = Two Irrigation. The experiment used a randomized complete block design (RCBD) with three replications. The maximum parameters, except for a few parameters related to growth, yield contribution, and yield, were significantly influenced by individual factor and their interactions. The interaction of variety and irrigation level V_1I_2 (binasoybean-1 and two irrigation events) resulted in the highest branch plant^{-1} (20.93), pod plant^{-1} (32.38), pod length (3.65 cm), seed pod^{-1} (3.89), 1000-seed weight (150.61 g), seed yield (2.24 t ha^{-1}), and stover yield (3.23 t ha^{-1}) among all the treatment combinations. The results of this study indicated that the four varieties presented marked variations in terms of plant growth characteristics and yield under water stress conditions. The variety Binasoybean-1 was relatively more water stress tolerant than the other varieties in respect to morphological adaptations associated with yield attributes and grain yield.

Keywords: Irrigation, soybean, variety, yield attributes, yield

INTRODUCTION
Soybean (*Glycine max*) accounts for approximately fifty percent of the total production of global oilseed crops. Soybean, including processed soybean products such as tofu, constitute good nutritional quality for adult humans and contain high amounts of protein (40–50 %), lipids (20–30 %) and carbohydrates (26–30 %), with more than eighty-five percent of its protein content being composed of β-conglycinin and glycinin (Gibbs *et al*. 2004). In Bangladesh, the total annual production is 107307.59 m ton from a cultivated area of 58940 hectares (BBS 2024) at 1.54 tons ha^{-1}, which is much lower than the world average of 2.79 t ha^{-1} (Miah *et al*. 2017). The socioeconomic conditions of these farming communities could be enhanced through the establishment of small soy-based food manufacturing industries, which produce milk, curd, flour, meat, halwa, biscuits and assorted snacks, all from soybean. In Bangladesh, there are ample

opportunities to increase both the area and productivity of oilseed crops such as soybean because of the availability of short-duration improved varieties and suitable agroclimatic conditions. These factors might enhance current oilseed production and processes and allow farmers to earn more from soybean cultivation (Miah *et al*. 2017)

The yield of soybean is very low in Bangladesh; however, this low yield is not an indication of the low yield potential of this crop. This may be attributed to a number of reasons, such as the unavailability of high-yield varieties with good quality, delayed sowing, fertilizer management, disease and insect infestation, improper or limited irrigation facilities, weeds and other stress conditions. Among the different factors, suitable variety and irrigation are the most important factors for low yield. Soybeans are relatively drought-tolerant crops but can respond well to irrigation. Soybeans respond well to irrigation during later growth stages, where water stress may lead to a decrease in yield. Water stress imposed during the preflowering and flowering stages reduces the yield of soybean plants by 28 and 24 %, respectively (Guntan and Evenson 1980). Similarly, various soybean cultivars show varying sensitivities to drought at different developmental stages (Momen *et al*. 1979). Irrigation and variety can play important roles in increasing the yield of soybean. It may be observed that irrigation had a significant effect on the highest yield of soybean. Agronomic traits such as grain yield and its components are the major selection criteria for evaluating drought tolerance under field conditions. The most sensitive stage for soybean plants is pod development to seed filling. Adequate water is needed in the soil to produce suitable yields. As soybean plants develop from the beginning of bloom through seed enlargement, their ability to tolerate water deficit decreases, resulting in low yields. Water deficit stress occurrence during the flowering and early pod development stages significantly increases the rate of pod abortion (Liu *et al*. 2003). The shortening of the grain-filling period due to water stress (Nakasathien *et al*. 2000) and the decrease in the transfer of assimilates into grains due to drought stress are two major reasons for the reduction in soybean grain weight. The protein and oil contents of soybean seeds may also be influenced by water stress. Drought may reduce the yield of soybean by approximately 40 % (Specht *et al*. 1999). In Bangladesh, soybean is planted during the post monsoon season when stored soil moisture rapidly decreases and the crop experiences drought at the reproductive stage. The need for water in soybean increases with plant development, peaking during the flowering–grain filling stages (7–8 mm day^{-1}) and decreasing thereafter (Bertolli *et al.* 2012). Therefore, the present study was undertaken to determine the efficacy of irrigation level and suitable variety on the maximum yield performance of soybean.

MATERIALS AND METHODS

The field experiment was conducted in the Agronomy Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, from November 2019 to March 2020. The climatic conditions of the experimental area include a subtropical climate. Typically, the rainfall is scarce during the period of November-March 2020. The experiment included four varieties, viz. Binasoybean-1 (V_1), Binasoybean-2 (V_2), Binasoybean-3 (V_3) and Binasoybean-4 (V_4) and three levels of irrigation, viz. no irrigation (I_0), one-time irrigation (I_1) during at 25days after sowing (DAS), and two-time irrigation (I_2) during at 25 and 50 DAS. The experiment was conducted in a randomized complete block design (RCBD) with three replications. The entire experimental area was divided into three blocks representing the replications, and each was subdivided into 12 plots. The unit plot size was 2.5 m × 2 m. The experimental field was first opened with a power tiller on 27 November 2019. Each unit plot was fertilized with urea, TSP, MoP and gypsum at rates of 50, 160, 100 and 100 kg ha^{-1}, respectively (BARI 2007), at the time of final land preparation. At physiological maturity, ten plants plot^{-1} were collected randomly: sun dried and plant height (cm), number of nodes plant^{-1}, number of branches plant^{-1}, number of filled pods plant^{-1}, number of unfilled pods plant^{-1}, number of seeds pod^{-1}, number of plants m^{-2}, 1000-seed weight (g), seed yield (t ha^{-1}) and stover yield (t ha^{-1}) were recorded. The data were analysed statistically via analysis of variance (ANOVA) with the help of a computer via the MSTAT-C program (Gomez and Gomez, 1984). The treatment means were compared via Duncan's multiple range test.

RESULTS AND DISCUSSION

Plant height (cm)

Significant variation in the plant height of soybean was recorded due to variety. Among the varieties, Binasoybean-1 presented the tallest plant height. (30.43 cm), whereas the lowest plant height (23.38 cm) was noted for Binasoybean-4 (Table 1). The differences in plant height reduction among the genotypes might be due mainly to genotypic differences. Similar results were also reported by Khan *et al.* (2014) in soybean. The height of soybean plants was significantly affected by different irrigation levels. The highest plant height (34.91 cm) was recorded when the crop was irrigated two times, whereas the lowest height (19.74 cm) was observed without irrigation (Table 2). The maximum plant height (40.82 cm) was observed in the V_1I_2 treatment, whereas the minimum height (17.37 cm) was noted in the V_4I_0 treatment (Table 3). The increase in this characteristic might be due to the positive effects of water on cell enlargement and cell division, as increasing the number of irrigations resulted in a progressively greater plant height. This may also be due to a decrease in relative turgidity and dehydration of the protoplasm, which is associated with a loss of turgor and reduced expansion of the cell and cell division.

Table 1. Effect of variety on yield attributes and yield of soybean

Varieties	PH	BP	PP	SP	TSW	SY	St. Y
V_1	30.43a	15.00a	23.59a	3.06a	127.93a	2.04a	2.29a
V_2	26.37b	11.53b	18.62b	2.86b	119.90b	1.50b	1.68ab
V_3	24.77c	10.522c	17.18bc	2.65c	116.66c	1.35c	1.54bc
V_4	23.38d	10.32c	15.92c	2.51c	115.40c	1.27c	1.41c
CV (%)	3.61	9.64	9.31	5.75	2.36	8.08	8.67
LS	**	**	**	**	**	**	**

Here, ** means at the 1% probability level; CV= coefficient of variation; LS= level of significant PH=plant height (cm); BP=branches plant^{-1} (cm); PP= pod plant^{-1} (no.); SP= seed pod^{-1}; TSW=thousand seed weight (g); SY= seed yield (t ha^{-1}); St.Y= stover yield (t ha^{-1}); V_1= binasoybean-1; V_2= binasoybean-2; V_3= binasoybean-3; V_4= binasoybean-4.

Table 2. Effect of irrigation on yield attributes and yield of soybean.

Irrigations	**PH**	**NB**	**PP**	**SP**	**TSW**	**GY**	**St. Y**
I_0	19.74c	8.04c	8.00c	2.02c	89.82c	0.84c	0.96c
I_1	24.06b	11.21b	15.92b	2.75b	126.47b	1.71b	1.92b
I_2	34.91a	16.27a	32.56a	3.53a	143.63a	2.07a	2.31a
CV (%)	3.61	9.64	9.31	5.75	2.36	8.08	8.67
LS	**	**	**	**	**	**	**

Here, ** means at the 1% level of probability, CV = coefficient of variation, LS = level of significant PH = plant height (cm), BP = branch plant^{-1} (cm), PP = pod plant^{-1} (no.); PL = pod length (cm), SP = seed pod^{-1}, TSW = thousand seed weight (g), SY = seed yield (t ha^{-1}), StY = stover yield (t ha^{-1}), irrigation: I_0 = rainfed (no irrigation), I_1 = one irrigation, and I_2 = two irrigations.

Branches plant^{-1} (no.)

The number of branches per plant significantly varied among the genotypes. Binasoybean-1 produced the highest number of branches per plant (15.00) (Table 1) whereas Binasoybean-4 produced the lowest number of branches per plant (10.32) (Table 1). The minimum number of branches per plant was recorded under the water deficit condition (8.049 cm), whereas the maximum was recorded at two irrigation levels (16.273 cm). (Table 2). The maximum number of branches plant^{-1} (20.93) was observed from V_1I_2, whereas the minimum number of branches plant^{-1} (7.59) was found in V_3I_0 at harvest (Table 3). The number of branches plant^{-1} is an important yield parameter that affects the number of pods plant^{-1} and, in turn, results in a relatively high yield (Anusha *et al*. 2021).

Pods plant^{-1} (no.)

The total number of pods per plant of soybean differed due to its various effects. The highest number of pods per plant was obtained (23.59) from Binasoybean-1, whereas the lowest number was found (15.92) from Binasoybean-4 (Table 1). Gawandi *et al*. (2002) reported significant variability in the number of pods per plant among genotypes. Different irrigation levels resulted in significant differences with respect to the number of pods per plant. The maximum number of pods plant^{-1} (32.56) was recorded from I_2, whereas the lowest number of pods plant^{-1} (8.00) was found in I_0 (Table 2). Binasoybean-1 produced the maximum number of pods per plant (32.38) when the crop was irrigated two times, whereas Binasoybean-4 produced the lowest number of pods per plant (16.15) when the crop was associated with no irrigation (Fig. 1). Gawandi *et al*. (2002) estimated significant variability among genotypes for the number of pods per plant. The results indicated that the weight of pods per plant significantly changed during the seasons of study, and the highest weight of pods per plant was observed in the first season. The comparison of the effects of the interaction between irrigation regime and season on the mean weight of pods per plant revealed that, compared with that of the control, the weight of pods per plant was affected in the same season. This result reconfirms the results of Mallarino *et al*. (2001).

Table 3. Effect of the interaction of variety and irrigation on the yield attributes and yield of soybean.

Interaction of variety and irrigation	**PH**	**BP**	**TSW**	**StY**
V_1I_0	21.92 f	9.44d	101.43e	1.14f
V_1I_1	28.56d	14.63b	131.74c	2.52b
V_1I_2	40.82a	20.93a	150.61a	3.23a
V_2I_0	20.26gh	7.67d	92.81f	1.00 fg
V_2I_1	24.38e	11.48c	124.78d	1.92cd
V_2I_2	34.48b	15.45b	142.11b	2.14c
V_3I_0	19.41 h	7.59d	83.55 g	0.90 fg
V_3I_1	22.04f	9.37d	124.48d	1.79d
V_3I_2	32.85c	14.59b	141.96b	1.93cd
V_4I_0	17.37 i	7.48d	81.48 g	0.83 g
V_4I_1	21.29 fg	9.37 d	124.89d	1.46e
V_4I_2	31.48c	14.11b	139.85b	1.95cd
CV (%)	3.61	9.64	2.36	8.67
LS	*	*	*	*

Here, * means at the 5% probability level, CV= coefficient of variation, LS= level of significance, PH=plant height (cm), BP=branches plant^{-1} (cm), PL= pod length (cm), SP= seed pod^{-1}, TSW=thousand seed weight (g), StY= stover yield (t ha^{-1}), V_1= binasoybean-1, V_2= binasoybean-2, V_3= binasoybean-3, V_4= binasoybean-4 and irrigation: I_0 = rainfed (no irrigation), I_1 = one irrigation, and I_2 = two irrigations.

Seed pod^{-1} (no.)

Statistically significant differences in the number of seeds per pod were detected due to varietal effects. The maximum number of seeds pod^{-1} (3.06) was recorded from Binasoybean-1, whereas the minimum number of seeds pod^{-1} (2.51) was observed from Binasoybean-4 (Table 1). The number of grains per pod is significantly affected by irrigation level. With lowering the irrigation level, the grain number per pod of soybean gradually decreased. The highest number of seeds pod^{-1} (3.53) was recorded from I_2, whereas the lowest number of seeds pod^{-1} (2.02) was found in I_0 (Table 2). The interaction effect between irrigation level and variety significantly affected the number of seeds per pod. The highest number of seeds pod^{-1} (2.55) was recorded from V_1I_2, whereas the lowest number of seeds pod^{-1} (1.56) was observed from both V_4I_0 (Fig. 2). These results indicated that, under water deficit conditions, the greatest decrease in the number of seeds per plant was observed during the periods of seed enlargement and pod formation, followed by the flowering period. The reduction was greater when drought stress was applied at the flowering stage. Karam *et al*. (2005) reported insignificant decreases in the number of seeds per plant in soybean plants grown under semiarid climate conditions and water deficit conditions during the flowering period and reported a 20% decrease compared with that under full irrigation during the seed enlargement period.

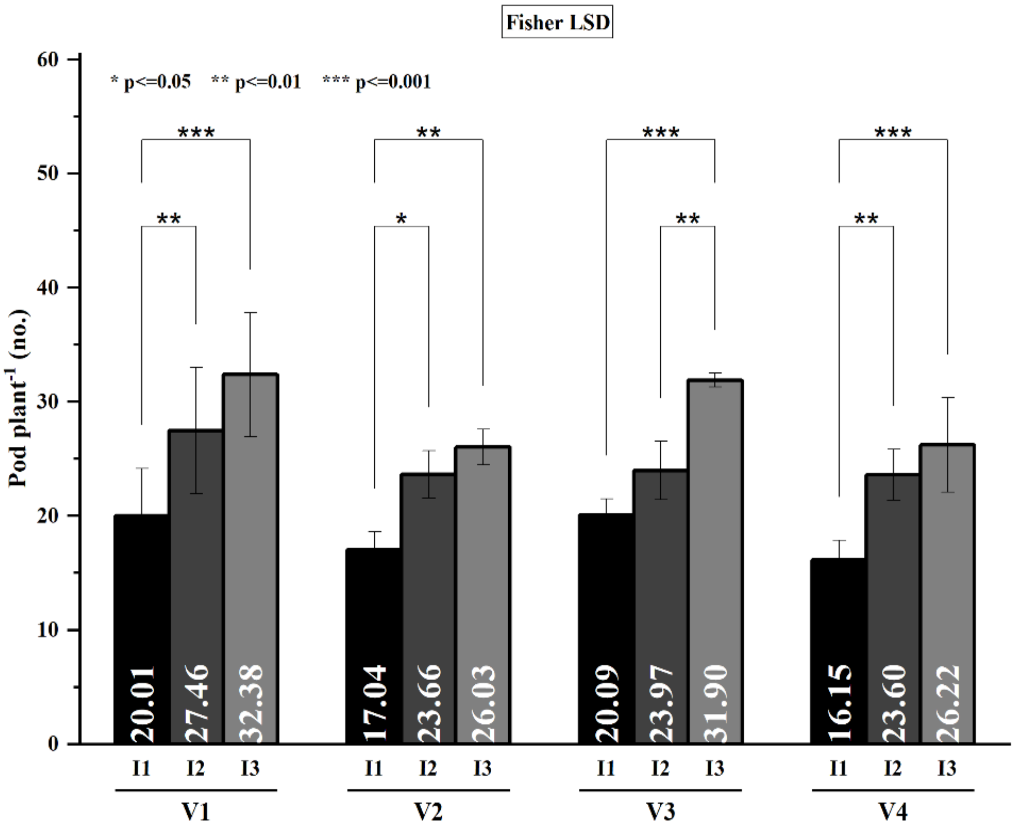

Fig. 1. Effect of the interaction of variety and irrigation on the POD activity of soybean plant-1. (* means at the 5% probability level, ** means at the 1% probability level). V_1= binasoybean-1, V_2= binasoybean-2, V_3= binasoybean-3, V_4= binasoybean-4 and irrigation: I_0 = rainfed (no irrigation), I_1 = one irrigation, and I_2 = two irrigations.

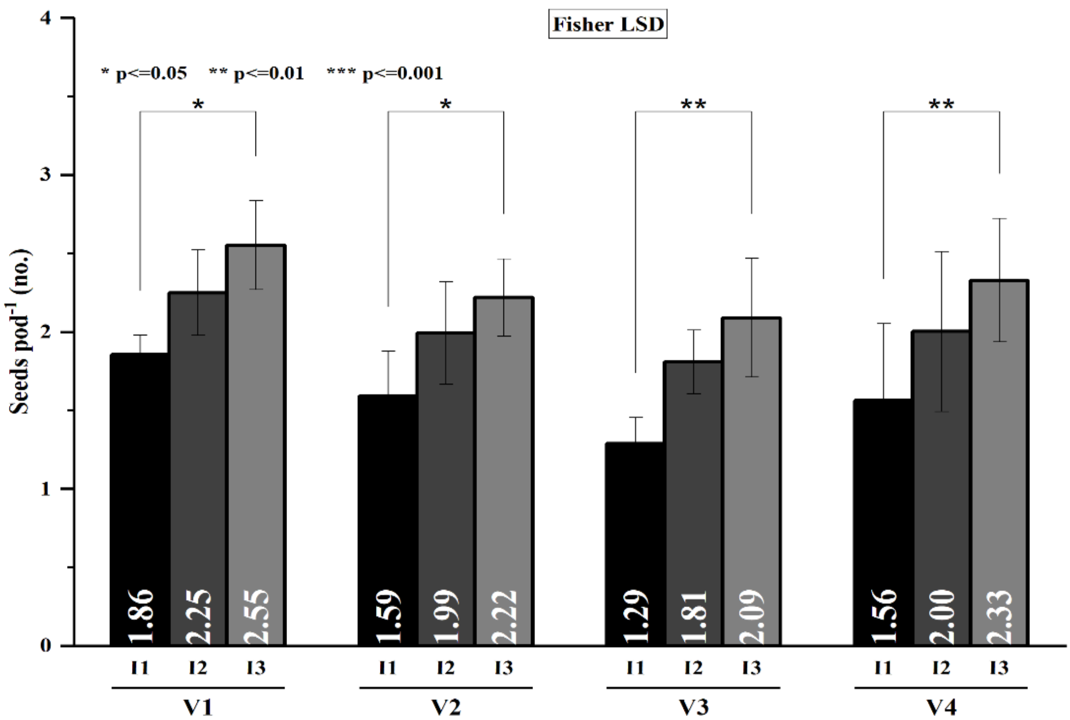

Fig. 2. Effect of the interaction of variety and irrigation on the seed pod^{-1} of soybean. (* means at the 5% probability level, ** means at the 1% probability level). V_1= binasoybean-1, V_2= binasoybean-2, V_3= binasoybean-3, V_4= binasoybean-4 and irrigation: I_0 = rainfed (no irrigation), I_1 = one irrigation, and I_2 = two irrigations.

1000-seed weight (g)

Statistically significant differences were found for the weight of 1000 seeds of soybean due to various effects. The highest weight of 1000-seed (127.93 g) was recorded from Binasoybean-1, whereas the lowest weight of 1000 seeds (115.4 g) was observed from Binasoybean-4 (Table 1). Chowdhury *et al.* (2015) reported that hundred-seed weight was significantly affected by sowing date and seed treatment**.** The weight of 1000 seeds of soybean differed significantly according to several irrigation levels. The interaction effect between water stress and variety significantly affected the weight of 1000 seeds. The highest weight of 1000-seed (150.61 g) was recorded from V_1I_2, whereas the lowest weight of 1000 seeds (81.48 g) was observed from V_4I_1 (Table 2). The number of seeds per pod and the seed weight were reported to be more stable and less affected by irrigation. Karam *et al*. (2005) reported significant decreases in the 1000-seed weight of soybean plants grown under semiarid climate conditions in Lebanon with water deficit during the flowering period and reported a 10% decrease compared with the water deficit treatment during the seed enlargement period.

Seed yield (t ha^{-1})

The grain yield significantly differed among the varieties. The maximum grain yield (2.04 t ha^{-1}) was observed in Binasoybean-1, while the minimum grain yield (1.27 t ha^{-1}) was found in Binasoybean-4 (Table 1). The grain yield of soybean varies significantly due to water stress. The grain yield of soybean gradually decreased without

proper irrigation. The highest grain yield (2.07 t ha^{-1}) was observed in $I_{2,}$ and the lowest grain yield (0.84 t ha^{-1}) was found in I_0 (Table 2). The soybean variety and irrigation level significantly affected the grain yield. The maximum grain yield (2.34 t ha^{-1}) was obtained from Binasoybean-1 when the crop was irrigated two times; the minimum yield (1.10 t ha^{-1}) was produced by Binasoybean-3 at zero irrigation (Fig. 3). Under improper water supply, all the high-yield soybean varieties produced few pods, which ultimately resulted in a low grain yield. Seed yield significantly decreased as the level of water deficit increased. These results indicated that soybean seed yield was significantly reduced when deficit irrigation was applied during flowering, pod formation, or seed enlargement, with soybeans exhibiting the greatest sensitivity to deficit irrigation at the seed enlargement stage. Dogan *et al*. (2007) reported decreased seed weights in soybean plants under water stress during the period of seed enlargement.

Straw yield

The results revealed that the straw yield of soybean was significantly influenced by various factors. The maximum straw yield (2.29 t ha^{-1}) was produced by Binasoybean-1, while Binasoybean-1 produced the lowest straw yield (1.41 tha^{-1}) (Table 1). The straw yield of soybean was significantly influenced by the irrigation levels . The highest straw yield (2.31 t ha^{-1}) was observed in I_2, whereas the lowest straw yield (0.96 t ha^{-1}) was found in I_0 (Table 2). The results revealed that the interactive effect of variety and irrigation level significantly affected the total amount of straw. Binasoybean-1 produced the maximum straw yield (3.23 t ha^{-1}) in $V_1 I_2$, whereas the lowest straw yield (0.83 t ha^{-1}) was produced by Binasoybean-4 in $V_4 I_0$ (Table 3).

The effects of variety and irrigation level on stover yield increased with increasing proper irrigation level, as reported by Anusha *et al*. (2021). However, all the varieties produced the maximum amount of straw with proper irrigation, as the environmental conditions were suitable for plant growth and provided enough time for maturation of the plants.

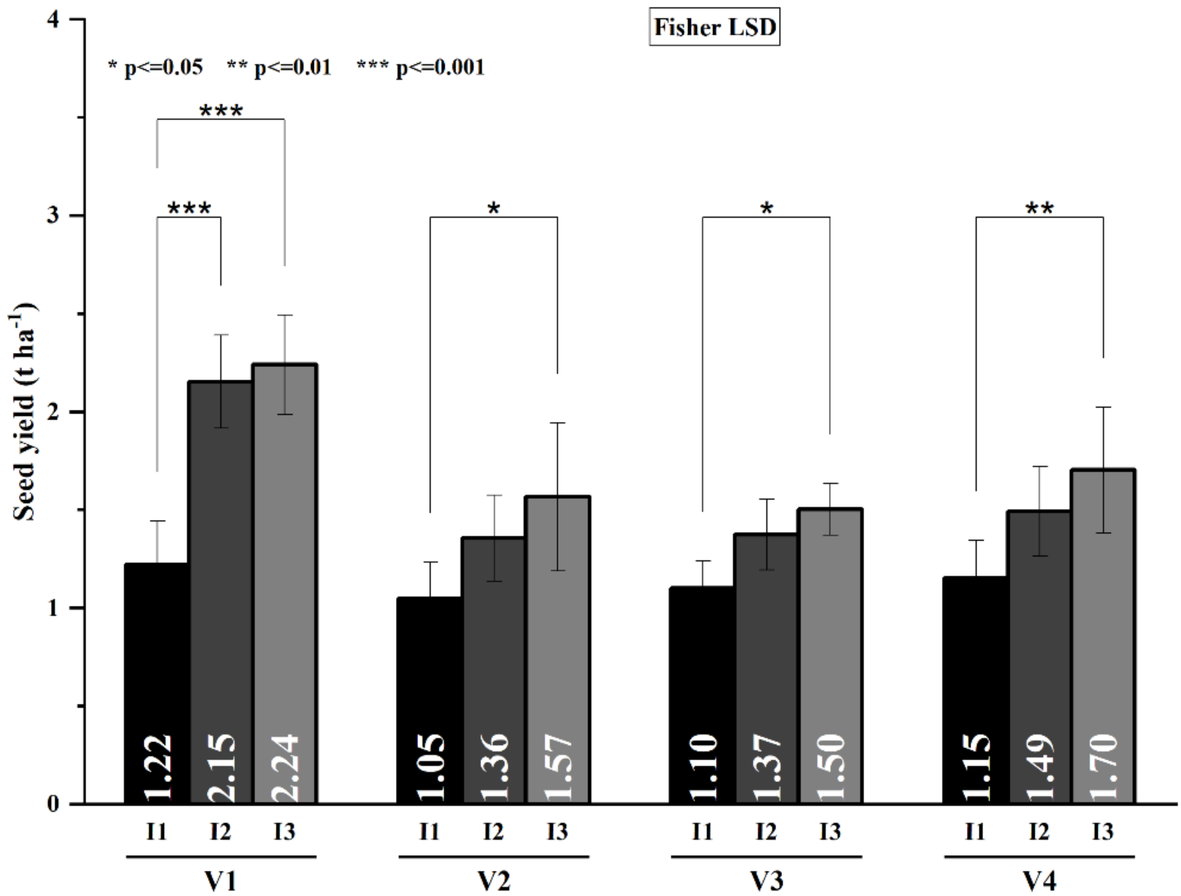

Fig. 3. Effect of the interaction of variety and irrigation on the seed yield (t ha^{-1}) of soybean. (* means at the 5% probability level, ** means at the 1% probability level). V_1= binasoybean-1, V_2= binasoybean-2, V_3= binasoybean-3, V_4= binasoybean-4 and irrigation: I_0 = rainfed (no irrigation), I_1 = one irrigation, and I_2 = two irrigations.

CONCLUSION

Among the yield contributing characteristics of soybean, plant height (cm), branch $plant^{-1}$ (cm), pod $plant^{-1}$ (no.), pod length (cm), pod^{-1}, thousand seed weight (g), yield (t ha^{-1}), and yield (t ha^{-1}) were significantly influenced by the individual effects of variety and irrigation as well as the interaction effects of variety and irrigation. Compared with the other varieties, Binasoybean-1 was relatively more water stress tolerant with respect to morphological characteristics with yield attributes and seed yield under water stress conditions.

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