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*Full Length Research Paper*

# The effect of different irrigation amounts and different doses of phosphorus-magnesium on the yield characteristics of soybean (*glycine max*. l.) under the conditions of semi-arid of the Harran Plain

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**This field trial was conducted to examine the effects of different doses of magnesium (Mg) and phosphorus (P) fertilizers on yield per decare (da), plant growth and yield characteristics of soybean plants grown with differing amounts of water. The experimental design was a randomized complete block with a split-split plot design with three replications, and was conducted in 2006 and 2007. Three different water levels (I1, I2, I3), four different doses of phosphorus (0, 4, 8 and 12 kg P da-1) and three different doses of magnesium (0, 4 and 8 kg Mg da-1) were administered. The cumulative pan values obtained from the class-A evaporation pan were 33% for I1, 67% for I2 and 100% for I3. The yield per da, plant height, node number, branch number, first soybean height, soybean number, soybean height and number of seeds per soybean were examined. Increasing water, magnesium and phosphorus increased the yield per decare, plant height, node number, branch number, first pod height, pod number, pod height and seeds per pod. Moreover, increasing water increased the height of the first pod, while increasing phosphorus and magnesium reduced first pod height.**

**Keywords**: Soybean, irrigation level, deficit irrigation, water management, phosphorus, magnesium, yield, quality, semi-arid area.

## INTRODUCTION

It had been shown that food consumption increases in parallel with population. Consumption of vegetable oils, which are important in human health and nutrition, also increases with population. This situation has led to a deficit in vegetable oil production, both in Turkey and around the world. This increasing deficit has highlighted the importance of vegetable oils and the need for increased production.

Global data on vegetable oil production for 2007 showed that soybean took the first place with 216.1 million tonnes, followed by cottonseed (72.5 million tonne), rapeseed (49.5 million tonne), peanut (34.9 million tonne) and sunflower (27.0 million tonne). During 2005 to 2007, soybean cultivation areas increased to 2 465,160 ha and its production showed an increase of 1899,649 ton. This increase in global soybean cultivation areas is a result of increased production in Brazil and Argentina (FAO Stat, 2007). In addition, an increase of 1 362 588 ha in sunflower cultivation areas has occurred. However, despite an increase of 2 744 333 ha in rapeseed cultivation areas, rapeseed production declined by 216 907 ton. A reduction of 224 223 ha in peanut cultivation areas resulted in a reduction in total production of 3 238 416 ton. Soybean had the largest cultivation area, followed respectively by cottonseed, rapeseed, sunflower, peanut and sesame. A periodical increase is observed in the cultivation area and production of soybeans. Moreover, there is a steady increase in

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sesame yield (FAO Stat, 2007).

As an alternative to second crops (aftercrops), soybean will become an important income source for manufacturers, due to its importance in the oil industry (DPT, 1989). In Turkey, soybean is cultivated on 33 000 ha, the total production is 75000 ton and the average yield is 294.1 kg $da^{-1}$. Approximately 95% of the total soyabean production of Turkey takes place in the Mediterranean Region (DIE, 2002). As a second crop, soybean is cultivated over an extent area in Turkey, especially in Cukurova region, second after wheat. Furthermore, after the completion of the development of Southeast Anatolian region (SAR), soya bean cultivation has been thought to be included in the 10% of the product composition (DPT, 1989). However, there is a lack of studies examining the irrigation and mineral requirements of this plant, as it is a very new product in the SAR.

In Turkey, arid and semi-arid climatic zone, the lack of sufficient natural rainfall to meet the water requirements of agricultural crops, results in reliance on irrigation. Despite the suitable soil resources and other climatic factors in the Northeast Anatolian plains, the lack of rainfall, especially in the spring and summer months, affects the agricultural development of the region. Overcoming the water deficiency, which restricts the application of modern agriculture methods, plant varieties and yield per plant, is seen as an important development that will increase agricultural production and employment opportunities and encourage other sectors and services (Tekinel, 1988).

Scarcity of irrigation water resources has resulted in an increase in the number of studies conducted in recent years on water saving. The limited availability of water resources for irrigation has recently led to a number of studies on water conservation. Projects are being implemented to examine the effects of deficit irrigation on crop yield. In cases where water resources are limited or costly, deficit irrigation programs, providing maximum production from unit water, should be implemented instead of total irrigation. Moreover, excessive use of water may cause soil salinization, desertification and soil erosion. Therefore, such problems could be reduced by means of deficit irrigation to some extent. A system of deficit irrigation management depends on the yield functions, revealing the relationship between water and yield (Nairizi and Ryzdewski, 1997).

In Turkey, N-P-K fertilizers are generally used in vegetative production and other macro and micro nutrition elements are not applied to the soil. However, the use of micro nutrition elements is as important as the use of macro nutrition elements for ensuring vegetative growth. Fertilizers applied to the soil are taken up by the plants as nutrients in the antagonistic and synergetic interaction environments. Over-fertilization causes pollution of the soil and changes chemical and physical process. In addition, excessive and unnecessary use of fertilizers, which already represent a very costly proportion of operating expenses, further increases operating costs, thus reduces the rate of return. Moreover, inefficient use of vegetative nutrients may lead to developmental abnormalities of plants

The study examined yield per decare, oil and protein content of seed, weight of 1000 seed weight, harvest index, above-ground biomass, chlorophyll content and root and stem dry weight for varying water deficits and different doses of phosphorus and magnesium.

## MATERIALS AND METHODS

This field trial was conducted at the trial and practice fields of Harran University Faculty of Agriculture in 2006 and 2007. The Nova variety of soybean (*Glycine max* L.) was used in the study. The field trial site is situated at 36º 42' N latitude and 38º 58' E longitude and is 464 m above sea level (KHSAE, 2001). Although the site is located within the northeast Anatolian climate zone, it is affected by the Mediterranean climate. The climate is characterized by warm to hot, dry summers and mild to cool, wet winters. During the growth period of soybean, between June and October in 2006, the average temperature varied from 20.6 to 30.8°C, minimum average temperature varied between 12.8 and 22.8°C, average precipitation was between 0 and 0.3 mm, average relative humidity was between 40.8 and 61.5% and the soil temperature varied between 23.9 and 36.6°C. During 2007, the average temperature varied between 21.6 and 30.4°C, minimum average temperature was between 16.5 and 23.0°C, average precipitation was between 0.8 and 25.9 mm, average relative humidity was between 36.9 and 47.7% and the soil temperature varied between 23.3 and 35.0°C.

The experimental design was a randomized complete block with a split-split plot design with three replications. Irrigation treatments constituted the main subjects and P and Mg applications constituted the sub-subjects. In the trial, three different water levels ($I_1$, $I_2$, $I_3$), 4 different doses of phosphorus (0, 4, 8 and 12 kg P $da^{-1}$) and 3 different doses of magnesium (0, 4 and 8 kg Mg $da^{-1}$) were administered. The cumulative pan values obtained from the class A evaporation pan were 33% for $I_1$, 67% for $I_2$, 100% for $I_3$. P applications were determined as $P_0$ (0 kg P $da^{-1}$), $P_1$ (4 kg P $da^{-1}$), $P_2$ (8 kg P $da^{-1}$), $P_3$ (12 kg P $da^{-1}$) and Mg applications were determined as $Mg_0$ (0 kg Mg $da^{-1}$), $Mg_1$ (4 kg Mg $da^{-1}$) and $Mg_2$ (8 kg Mg $da^{-1}$).

Phosphorus and Mg were applied to the trial plots as the following combinations.

| | | | |
|---|---|---|---|
| $P_0Mg_0$ | $P_1Mg_0$ | $P_2Mg_0$ | $P_3Mg_0$ |
| $P_0Mg_1$ | $P_1Mg_1$ | $P_2Mg_1$ | $P_3Mg_1$ |
| $P_0Mg_2$ | $P_1Mg_2$ | $P_2Mg_2$ | $P_3Mg_2$ |

In this study, triple super-phosphate was used as a P resource and magnesium sulphate ($MgSO_4.7H_2O$) was used as a Mg resource. These were applied to the plots during the planting process in a way that allows all plant lines to gain equal amounts of nutrients and not to allow two kinds of fertilizers to be applied together. After the planting and fertilization processes, a drip irrigation system was established and first irrigation was carried out. After the soybean outlet and when the soil humidity fell to 40%, treatment irrigation was started.

## RESULTS AND DISCUSSION

This study examined the yield, plant height, number of

**Table 1.** Mean yield per decare (kg $da^{-1}$) and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 Irrigation treatment | | | Average | 2007 Irrigation treatment | | | Average |
|---|---|---|---|---|---|---|---|---|
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 111.07 s | 128.87 s | 326.60 l | 188.84 | 107.40 r | 130.93 q | 335.33 j | 191.22 |
| $P_0Mg_1$ | 126.83 s | 139.20 rs | 382.80 hu | 216.28 | 125.50 qr | 139.10 pq | 351.17 ıj | 205.26 |
| $P_0Mg_2$ | 132.10 rs | 160.93 pqr | 447.17 cd | 246.73 | 131.93 q | 163.93 o | 451.73 d | 249.20 |
| $P_1Mg_0$ | 134.73 rs | 131.17 rs | 432.30 def | 232.73 | 121.30 qr | 174.00 o | 406.97 ef | 234.09 |
| $P_1Mg_1$ | 140.77 qrs | 171.93 pq | 492.53 b | 268.41 | 140.17 pq | 196.90 n | 496.43 c | 277.83 |
| $P_1Mg_2$ | 162.00 pqr | 203.50 o | 564.50 a | 310.00 | 156.53 op | 216.90 mn | 517.90 ab | 297.11 |
| $P_2Mg_0$ | 207.80 no | 369.40 jk | 386.40 hıj | 321.20 | 219.83 lm | 377.57 gh | 418.17 e | 338.52 |
| $P_2Mg_1$ | 217.40 mno | 424.47 d-e | 405.77 f-ı | 349.21 | 239.57 kl | 397.97 efg | 509.83 bc | 382.46 |
| $P_2Mg_2$ | 235.07 mn | 468.07 bc | 444.43 cd | 382.52 | 250.17 k | 445.10 d | 533.57 a | 409.61 |
| $P_3Mg_0$ | 188.00 op | 377.33 ıj | 338.50 kl | 301.28 | 219.87 lm | 370.27 hı | 340.47 j | 310.20 |
| $P_3Mg_1$ | 243.50 m | 378.70 ıj | 396.07 g-j | 339.42 | 243.40 k | 387.83 fgh | 379.83 gh | 337.02 |
| $P_3Mg_2$ | 345.17 kl | 440.63 cde | 411.77 e-h | 399.19 | 334.17 j | 411.13 e | 413.20 e | 386.17 |
| Average | 187.04 | 282.85 | 419.07 | 188.84 | 107.40 r | 130.93 q | 335.33 j | 191.22 |
| LSD (0.05) | 31.450 (Fertilizer levels × Irrigation treatments) | | | | 21.010 (Fertilizer levels × Irrigation treatments) | | | |

nodes, number of branches, the height of first soybean, number of soybean, height of soybean and number of seeds per soybean.

### The effects of water, P and Mg on the yield per decare

Yield per decare ranged between 111.07 and 564.50 kg $da^{-1}$ in the first year and between 107.40 and 533.57 kg $da^{-1}$ in the second year. In the first year, the highest value was obtained from $I_3$ and $P_1Mg_2$ application, while in the second year it was obtained from $P_2Mg_2$ application with the same irrigation treatment. In both years, increasing water levels also increased the yields per decare (Table 1). This result is similar to several previous studies, which also reported that increasing water levels increased the yield per decare of soyabean (Vasiliu et al., 1977; Yavada, 1980; Bayrak, 1989; Casanova, 2000; Saadi and Yazdi-Samadi, 1978; Sarma et al., 1976; Saenko, 1977; Fernandez et al., 1978; Simiciklas et al., 1989; Muandemele et al., 1988; Specht and Gordon, 2000; ßim□ek et al., 2001).

Furthermore, increasing P and Mg levels increased the yield per decare in both years. In the first year, the highest yield was obtained from $I_3$ and $P_1Mg_2$ and from $P_2Mg_2$ combination using the same irrigation treatment in the second year. Studies by Casanova (2000), Bhangoo and Albritton (1972), Paikera et al. (1988), Tomar et al. (1993), Turkhede et al. (1993), Hasnabade et al. (1990), Jayapaul and Ganesaraja (1990), Misra et al. (1990), and Reddy et al. (1990) also indicated that different doses of P increased the yield per decare of soybean. Abdel-Gawad et al. (1989) reported that foliar fertilizers, including Mg and different forms of other micro-elements, increased the yield of soyabean in two different periods.

It was understood that Mg application to the soil increased the yield when compared to global soybean yields world. Mg has an important role in increasing yields in conditions where the reduction of irrigation and fertilization is necessary. Although the results of our study are similar to previous studies in the literature, the yield per decare was higher in some combinations than the values reported in the literature. The idea of fertilization with Mg was first proposed by Mermut et al. (1996), who suggested that Mg enabled the intake of P from the soil. Higher soybean production in the present study compared with the values reported in the literature is probably the result of soil fertilization with Mg.

### The effects of water, P and Mg on plant height

Plant heights ranged between 49.43 and 106.67 cm in the first year and between 46.51 and 110.77 cm in the second year. In the first year, the highest value was obtained from $I_3$ irrigation treatment and $P_2Mg_0$ combination, and from $I_3$ irrigation treatment and $P_0Mg_1$ combination in the second year. In both years, increasing water levels also increased plant heights (Table 2). Furthermore, it is also notable that, in the first year of the study, increasing phosphorus levels to the $P_2$ phosphorus level (8 kg $da^{-1}$) had a large effect on plant height, while increasing magnesium levels had a moderate effect positive. In the second year, increasing phosphorus levels reduced the plant height, while increasing magnesium levels again had a moderate positive effect (Table 2). Such a difference between the two study years

**Table 2.** Mean plant height (cm) and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 | | | Average | 2007 | | | Average |
|---|---|---|---|---|---|---|---|---|
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 52.13 lm | 61.90 ıj | 88.20 fg | 67.41 | 49.31 mn | 74.93 fgh | 103.47 ab | 75.90 |
| $P_0Mg_1$ | 49.43 m | 65.80 hı | 94.80 d-g | 70.01 | 49.67 mn | 74.63 fgh | 110.77 a | 78.36 |
| $P_0Mg_2$ | 51.97 lm | 61.67 ıj | 104.57 abc | 72.73 | 46.51 n | 52.40 lmn | 82.67 d-g | 60.51 |
| $P_1Mg_0$ | 54.03 klm | 66.23 hı | 101.13 a-d | 73.80 | 48.30 mn | 62.13 ı-l | 89.00 cd | 66.48 |
| $P_1Mg_1$ | 54.97 j-m | 71.27 h | 99.23 b-e | 75.16 | 50.87 lmn | 76.57 fgh | 106.47 ab | 77.97 |
| $P_1Mg_2$ | 54.70 j-m | 71.00 h | 106.40 ab | 77.37 | 50.63 lmn | 68.80 h-k | 85.07 c-f | 68.17 |
| $P_2Mg_0$ | 61.87 ıj | 94.50 d-g | 106.67 a | 87.68 | 58.90 j-m | 70.13 hıj | 94.80 bc | 74.61 |
| $P_2Mg_1$ | 64.10 hı | 97.30 cde | 95.73 de | 85.71 | 55.45 lmn | 71.27 ghı | 88.60 cde | 71.77 |
| $P_2Mg_2$ | 63.20 ı | 95.70 de | 93.67 efg | 84.19 | 57.38 k-n | 76.40 fgh | 103.73 ab | 79.17 |
| $P_3Mg_0$ | 61.33 ıjk | 96.30 de | 93.47 efg | 83.70 | 57.07 k-n | 71.83 ghı | 76.87 e-h | 68.59 |
| $P_3Mg_1$ | 58.83 ı-l | 96.10 de | 96.17 de | 83.70 | 57.05 k-n | 72.50 ghı | 76.80 e-h | 68.78 |
| $P_3Mg_2$ | 60.73 ıjk | 95.46 def | 87.57 g | 81.25 | 55.97 lmn | 76.27 fgh | 85.13 c-f | 72.46 |
| Average | | 57.28 | 81.10 | 97.30 | 53.10 | 70.66 | 91.94 | |
| LSD (0.05) | 0.419 (Fertilizer levels × Irrigation treatments) | | | | 11.830 (Fertilizer levels × Irrigation treatments) | | | |

is considered to result from the climate. Atakisi and Arioglu (1983) reported that, in the cultivation of soybean as a second crop in the Cukurova region, N and P fertilizers applied to the soil together with bacteria inoculation had an impact on plant height; the highest plant height was 106.71 cm, obtained from the 2.5 kg N $da^{-1}$ and 4 kg P $da^{-1}$ application. Dadson and Acquaah (1984) and Jayapaul and Ganesaraja (1990) indicated N and P applications, and Bharati et al. (1986) indicated P applications as greatly increasing plant height in soybean plants. A study by Bakaloglu and Aycicegi (2005) reported a mean plant height of 91.30 cm. The results of our study show some similarities with the aforementioned studies and the plant heights obtained are in agreement with the values reported in the literature.

## The effects of Water, P and Mg on the number of nodes

The number of nodes per plant ranged between 12.63 and 18.57 in the first year and between 12.43 and 17.80 per plant in the second year; the highest number of nodes in the first year was obtained from $I_3$ irrigation treatment and $P_1Mg_2$ application and from $I_3$ irrigation treatment and $P_2Mg_2$ application in the second year (Table 3). In both years, increasing water levels also increased the number of nodes.

Moreover, increased P also greatly increased the number of nodes in the first year; increased magnesium levels increased the node number remarkably, except for the $P_3$ phosphorus level (8 kg $da^{-1}$); and such Mg levels affected the number of nodes to a smaller extent at the $P_3$ phosphorus level positive. In the second year, increasing P levels decreased the number of nodes, while increasing levels of Mg affected it positively to a smaller extent. Dadson and Acquaah (1984), and Atakisi and Arioglu (1983) indicated that N and P application together with the bacteria inoculation increased the node number of soybeans at a significant level. The results of our study show some similarities with the aforementioned studies and the node numbers are generally in conformity with the values reported in the literature.

## The effects of water, P and Mg on the branch number

Number of branches ranged between 1.43 and 3.00 number/plant in the first year and between 1.27 and 2.80 number/plant in the second year, and the highest values were obtained from $I_3$ irrigation treatment and $P_3Mg_0$ application in both years (Table 4). In both years, increasing water levels also increased the number of branch.

Moreover, increasing P also increased the number of branches at a significant level and increasing Mg increased number of branches, except for phosphorus at the $P_3$ level (8 kg $da^{-1}$), and decreased it at the $P_3$ phosphorus level in both years (Table 4). Bakaloglu and Aycicegi (2005) reported that the average number of branches per plant was 1.93. The results of our study show some similarities with the aforementioned studies and the number of branches are generally in conformity with the values reported in the literature. On the other hand, the study carried out by Sepetoglu and Nasır (1988) examining the effect of different doses of phosphorus and nitrogen and bacteria inoculation on the yield and yield characteristics of soya bean showed that

**Table 3.** Mean number of nodes and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 Irrigation treatment $I_1$ | 2006 Irrigation treatment $I_2$ | 2006 Irrigation treatment $I_3$ | Average | 2007 Irrigation treatment $I_1$ | 2007 Irrigation treatment $I_2$ | 2007 Irrigation treatment $I_3$ | Average |
|---|---|---|---|---|---|---|---|---|
| $P_0Mg_0$ | 14.83 g-l | 14.83 g-l | 15.47 d-l | 15.04 | 14.33 e-l | 13.80 g-l | 17.07 ab | 15.07 |
| $P_0Mg_1$ | 12.63 m | 15.83 b-k | 16.73 a-h | 15.07 | 12.43 l | 15.13 b-h | 16.40 a-e | 14.66 |
| $P_0Mg_2$ | 14.17 ı-m | 16.83 b-ı | 17.17 a-f | 15.89 | 13.27 h-l | 13.40 h-l | 15.80 a-g | 14.16 |
| $P_1Mg_0$ | 13.40 lm | 16.03 b-j | 17.93 ab | 15.79 | 13.53 h-l | 13.47 h-l | 16.47 a-d | 14.49 |
| $P_1Mg_1$ | 15.00 f-l | 16.27 b-ı | 16.93 a-g | 16.07 | 14.63 d-j | 14.73 c-j | 16.40 a-e | 15.26 |
| $P_1Mg_2$ | 14.87 g-l | 16.57 a-h | 18.57 a | 16.67 | 14.67 d-j | 14.20 f-l | 16.07 a-f | 14.98 |
| $P_2Mg_0$ | 14.67 h-m | 15.73 c-k | 15.93 b-k | 15.44 | 12.93 ı-l | 13.53 h-l | 16.80 abc | 14.42 |
| $P_2Mg_1$ | 15.20 e-l | 17.27 a-e | 16.10 b-j | 16.19 | 14.60 d-k | 14.07 f-l | 13.87 g-l | 14.18 |
| $P_2Mg_2$ | 14.97 g-l | 17.33 a-e | 16.43 a-h | 16.24 | 13.70 h-l | 13.93 g-l | 17.80 a | 15.14 |
| $P_3Mg_0$ | 13.77 klm | 17.47 a-d | 17.83 abc | 16.36 | 14.20 f-l | 14.40 d-l | 14.93 c-ı | 14.51 |
| $P_3Mg_1$ | 14.07 j-m | 17.00 a-g | 17.43 a-d | 16.17 | 12.80 jkl | 14.87 c-j | 15.00 b-ı | 14.22 |
| $P_3Mg_2$ | 13.83 klm | 17.70 abc | 17.43 a-d | 16.32 | 12.53 kl | 15.10 b-h | 14.87 c-j | 14.17 |
| Average | 14.28 | 16.53 | 17.00 | | 13.64 | 14.22 | 15.96 | |
| LSD (0.05) | 2.18 (Fertilizer levels × Irrigation treatments) | | | | 2.07 (Fertilizer levels × Irrigation treatments) | | | |

**Table 4.** Mean number of branches and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 200.

| Fertilizer level | 2006 Irrigation treatment $I_1$ | 2006 Irrigation treatment $I_2$ | 2006 Irrigation treatment $I_3$ | Average | 2007 Irrigation treatment $I_1$ | 2007 Irrigation treatment $I_2$ | 2007 Irrigation treatment $I_3$ | Average |
|---|---|---|---|---|---|---|---|---|
| $P_0Mg_0$ | 2.23 a-e | 1.57 cde | 1.87 cde | 1.89 | 2.07 a-e | 1.47 def | 1.67 def | 1.73 |
| $P_0Mg_1$ | 2.30 a-e | 2.33 a-e | 1.93 b-e | 2.19 | 1.93 b-f | 1.67 def | 1.87 c-f | 1.82 |
| $P_0Mg_2$ | 1.93 b-e | 1.43 e | 1.87 cde | 1.74 | 1.73 def | 1.20 f | 1.47 def | 1.47 |
| $P_1Mg_0$ | 1.90 cde | 1.93 b-e | 2.17 a-e | 2.00 | 1.53 def | 1.73 def | 1.87 c-f | 1.71 |
| $P_1Mg_1$ | 2.57 abc | 2.03 a-e | 1.47 de | 2.02 | 1.93 b-f | 1.80 c-f | 2.13 a-d | 1.96 |
| $P_1Mg_2$ | 2.17 a-e | 2.13 a-e | 1.97 b-e | 2.09 | 1.93 b-f | 1.80 c-f | 1.93 b-f | 1.89 |
| $P_2Mg_0$ | 1.80 cde | 2.10 a-e | 1.87 cde | 1.92 | 1.53 def | 2.00 a-f | 1.80 c-f | 1.78 |
| $P_2Mg_1$ | 1.93 b-e | 2.30 a-e | 2.47 a-d | 2.23 | 1.53 def | 2.60 abc | 2.20 a-d | 2.11 |
| $P_2Mg_2$ | 1.67 cde | 2.93 ab | 1.73 cde | 2.11 | 1.60 def | 2.73 ab | 1.27 ef | 1.87 |
| $P_3Mg_0$ | 1.67 cde | 2.17 a-e | 3.00 a | 2.28 | 1.73 def | 1.93 b-f | 2.80 a | 2.16 |
| $P_3Mg_1$ | 1.50 de | 2.20 a-e | 2.13 a-e | 1.94 | 1.27 ef | 1.93 b-f | 2.07 a-e | 1.76 |
| $P_3Mg_2$ | 1.63 cde | 1.93 b-e | 1.93 b-e | 1.83 | 1.80 c-f | 1.67 def | 1.60 def | 1.69 |
| Average | 1.94 | 2.09 | 2.03 | | 1.72 | 1.82 | 1.89 | |
| LSD (0.05) | 1.02 (Fertilizer levels × Irrigation Treatments) | | | | 0.85 (Fertilizer levels × Irrigation Treatments) | | | |

said factors do not have an impact on the branch number. Our findings are in contradiction with their findings.

## The effects of water, P and Mg on the first pod height

The height of the first pod values ranged between 7.03 to 15.77 cm in the first year and 10.23 to 17.90 cm in the second year and the highest values were obtained from $I_2$ irrigation treatment and $P_0Mg_0$ application in the first year and from $I_2$ irrigation treatment and $P_2Mg_1$ application in the second year. In both years, increasing water levels also increased the values of height first pod (Table 5).

Furthermore, increasing P in the first year decreased the height the first pod at a significant level and increasing magnesium increased the first pod height, except for the $P_0$ phosphorus level (0 kg P $da^{-1}$), and decreased it at the $P_0$ phosphorus level in both years (Table 6). In the second year, increasing phosphorus decreased the first pod height at a significant level and increasing magnesium levels increased the first pod

**Table 5.** Mean first pod height (cm) and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 Irrigation treatment | | | Average | 2007 Irrigation treatment | | | Average |
|---|---|---|---|---|---|---|---|---|
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 9.20 k-p | 15.77 a | 12.57 b-ı | 12.51 | 15.23 b-h | 15.17 b-h | 15.80 a-f | 15.40 |
| $P_0Mg_1$ | 8.60 l-p | 13.77 a-d | 12.60 b-ı | 11.66 | 14.80 d-ı | 16.13 a-d | 12.13 klm | 14.36 |
| $P_0Mg_2$ | 7.03 p | 13.00 a-h | 14.60 ab | 11.54 | 16.00 a-d | 15.07 c-h | 15.83 a-f | 15.63 |
| $P_1Mg_0$ | 9.97 ı-o | 13.17 a-g | 12.33 b-j | 11.82 | 11.23 lm | 17.47 ab | 13.60 e-l | 14.10 |
| $P_1Mg_1$ | 10.60 f-n | 14.80 ab | 12.40 b-ı | 12.60 | 10.23 m | 17.40 abc | 13.20 g-l | 13.61 |
| $P_1Mg_2$ | 11.70 c-k | 11.33 c-l | 12.53 b-ı | 11.86 | 11.43 lm | 16.40 a-d | 15.80 a-f | 14.54 |
| $P_2Mg_0$ | 7.43 op | 10.20 h-o | 13.10 a-g | 10.24 | 15.93 a-e | 15.33 b-h | 14.27 d-k | 15.18 |
| $P_2Mg_1$ | 10.57 f-n | 10.67 e-n | 13.53 a-e | 11.59 | 15.57 a-g | 17.90 a | 12.27 j-m | 15.24 |
| $P_2Mg_2$ | 8.67 l-p | 9.33 k-p | 11.07 d-m | 9.69 | 15.80 a-f | 15.67 a-f | 12.43 ı-m | 14.63 |
| $P_3Mg_0$ | 8.37 m-p | 11.93 b-k | 10.73 e-n | 10.34 | 14.60 d-j | 17.20 abc | 13.53 f-l | 15.11 |
| $P_3Mg_1$ | 8.00 nop | 10.40 g-n | 13.33 a-f | 10.58 | 15.80 a-f | 13.00 h-l | 12.60 ı-m | 13.80 |
| $P_3Mg_2$ | 9.50 j-p | 10.03 ı-o | 14.03 abc | 11.19 | 12.43 ı-m | 13.27 g-l | 13.27 g-l | 12.99 |
| Average | 9.14 | 12.03 | 12.74 | | 14.09 | 15.83 | 13.73 | |
| LSD (0.05) | 2.89 (Fertilizer levels × Irrigation treatments) | | | | 2.37 (Fertilizer levels × Irrigation treatments) | | | |

height to a lesser extent to positive, except for phosphorus at the $P_3$ level (12 kg $da^{-1}$) and decreased it at the $P_3$ phosphorus level in both years (Table 5). Atakisi and Arioglu (1983) reported that N and P application together with the bacteria inoculation in the cultivation of soybean as a second crop in the Çukurova region did not affect the first pod height significantly. Bakaloglu and Aycicegi (2005) reported the average first pod height as 18.57 cm. The results of our study show some similarities with the aforementioned studies and the first pod heights generally agree with the values reported in the literature.

### The effects of water, P and Mg on number of pods

Pod number values ranged between 32.70 and 78.77 number/plant in the first year (2006) and between 29.80 and 67.40 number/plant in the second year and the highest values were obtained from $I_3$ irrigation treatment and $P_1Mg_2$ application in both years (Table 6). In both years, increasing water levels also increased the values of pod number. The study conducted by Saadi and Yazdi-Samadi (1978) on the effects of water and certain chemical fertilizer on the yield of Clark 63 cultivar of soya bean showed that water and phosphorus jointly increased the pod number. The field study of Muandemele et al. (1988) showed that aridity reduces the pod/plant, seed/pod ratio and the seed yield and exposure to aridity causes small seeds and reduces the germination power in 30 soya species.

Moreover, increasing phosphorus and magnesium levels have also increased the pod number significantly in both years (Table 6). Dadson and Acquaah (1984), and Sepetoglu and Nasir (1988) indicated that nitrogen and phosphorus applications to the soil together with the bacteria inoculation increased the pod number considerably. Paikera et al. (1988), and Jayapaul and Ganasaraja (1990) reported increasing doses of phosphorus increased the pod number of the soya bean to a significant extent and the highest pod number was said by Jayapaul and Ganasaraja (1990) to be obtained from the dose of 12 kg P $da^{-1}$, while it was said by Paikera et al. (1988) to be obtained from the dose of 4 kg N $da^{-1}$ + 4 kg P $da^{-1}$. The results of our study show some similarities with the aforementioned studies and the number of pods per plant is generally in agreement with the values reported in the literature. Bakaloglu and Aycicegi (2005) determined the average number of pods as 44.30 per soya bean plant. In comparison, our study showed an increase, depending on the irrigation and fertilization combinations.

### The effects of water, P and Mg on height of pod

Height of pod values ranged between 2.67 and 3.93 cm in the first year and between 2.17 and 4.07 cm in the second year; the highest values were obtained from $I_3$ irrigation treatment and $P_0Mg_2$ and $P_1Mg_2$ applications in the first year, and from $I_3$ irrigation treatment and $P_0Mg_2$ application in the second year. In both years, increasing water levels also increased the pod height. Furthermore, increasing P and Mg levels increased the pod height significantly in both years (Table 7).

### The effects of water, P and Mg on number of seeds per pod

The number of seeds per pod ranged between 2.53 and 3.33 in the first year and between 2.00 and 3.20 in the

**Table 6.** Mean number of pods and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 | | | $I_1$ | 2007 | | | Average |
|---|---|---|---|---|---|---|---|---|
| | Irrigation treatment | | | | Irrigation treatment | | | |
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 41.03 m-o | 32.70 q | 48.77 ı-l | 40.83 | 44.90 m-q | 29.80 t | 54.03 e-ı | 42.91 |
| $P_0Mg_1$ | 44.77 j-o | 35.83 pq | 63.70 b-e | 48.10 | 45.87 l-p | 31.27 t | 59.90 bcd | 45.68 |
| $P_0Mg_2$ | 46.17 j-n | 39.60 nop | 66.57 bcd | 50.78 | 47.20 j-o | 34.20 st | 62.07 abc | 47.82 |
| $P_1Mg_0$ | 39.27 opq | 41.53 m-p | 55.73 fgh | 45.51 | 41.57 o-r | 37.40 rs | 49.73 ı-m | 42.90 |
| $P_1Mg_1$ | 43.63 l-m | 44.77 j-o | 63.63 b-e | 50.68 | 42.27 o-r | 43.07 n-r | 55.47 d-h | 46.93 |
| $P_1Mg_2$ | 44.33 j-o | 50.40 hıj | 78.77 a | 57.83 | 45.33 l-p | 48.07 j-n | 67.40 a | 53.60 |
| $P_2Mg_0$ | 45.07 j-o | 56.07 fgh | 54.13 f-ı | 51.76 | 40.60 pqr | 53.77 f-ı | 50.60 g-l | 48.32 |
| $P_2Mg_1$ | 48.53 ı-l | 60.07 def | 60.57 def | 56.39 | 45.57 l-p | 58.20 c-f | 55.33 d-ı | 53.03 |
| $P_2Mg_2$ | 50.90 hıj | 65.50 bcd | 64.50 bcd | 60.30 | 50.00 g-m | 59.50 b-e | 64.07 ab | 57.86 |
| $P_3Mg_0$ | 43.80 k-o | 50.27 h-k | 57.90 efg | 50.66 | 39.47 qrs | 46.67 k-o | 51.67 g-k | 45.93 |
| $P_3Mg_1$ | 46.53 j-m | 60.53 def | 63.27 cde | 56.78 | 41.97 o-r | 49.80 h-m | 55.40 d-ı | 49.06 |
| $P_3Mg_2$ | 53.43 ghı | 67.40 bc | 70.07 b | 63.63 | 52.63 f-j | 55.67 d-g | 63.20 abc | 57.17 |
| Average | 45.62 | 50.39 | 62.30 | | 44.78 | 45.62 | 57.41 | |
| LSD (0.05) | 6.599 (Fertilizer levels × Irrigation treatments) | | | | 5.677 (Fertilizer levels × Irrigation treatments) | | | |

**Table 7.** Mean pod height (cm) and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 | | | Average | 2007 | | | Average |
|---|---|---|---|---|---|---|---|---|
| | Irrigation Treatments | | | | Irrigation Treatments | | | |
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 2.67 m | 3.03 jkl | 3.33 f-j | 3.01 | 2.40 op | 3.03 klm | 3.33 e-k | 2.92 |
| $P_0Mg_1$ | 2.83 lm | 2.97 klm | 3.57 b-f | 3.12 | 2.53 nop | 3.43 d-j | 3.60 b-g | 3.19 |
| $P_0Mg_2$ | 2.93 klm | 3.40 e-ı | 3.93 a | 3.42 | 2.63 no | 3.73 a-d | 4.07 a | 3.48 |
| $P_1Mg_0$ | 2.93 klm | 3.10 ı-l | 3.07 jkl | 3.03 | 2.17 p | 3.27 g-k | 2.87 lmn | 2.77 |
| $P_1Mg_1$ | 2.93 klm | 3.43 e-h | 3.57 b-f | 3.31 | 2.63 no | 3.60 b-g | 3.43 d-j | 3.22 |
| $P_1Mg_2$ | 3.03 jkl | 3.50 c-g | 3.93 a | 3.49 | 2.83 lmn | 3.70 a-e | 3.93 ab | 3.49 |
| $P_2Mg_0$ | 3.07 jkl | 3.40 e-ı | 3.20 g-k | 3.22 | 2.70 mno | 3.20 h-l | 3.17 ı-l | 3.02 |
| $P_2Mg_1$ | 3.17 h-k | 3.67 a-e | 3.40 e-ı | 3.41 | 3.20 h-l | 3.50 c-ı | 3.47 c-ı | 3.39 |
| $P_2Mg_2$ | 3.47 d-h | 3.87 ab | 3.60 b-f | 3.64 | 3.47 c-ı | 3.83 abc | 3.70 a-e | 3.67 |
| $P_3Mg_0$ | 3.10 ı-l | 3.20 g-k | 3.23 g-k | 3.18 | 2.87 lmn | 3.17 ı-l | 3.07 j-m | 3.03 |
| $P_3Mg_1$ | 3.17 h-k | 3.40 e-ı | 3.50 c-g | 3.36 | 3.30 f-k | 3.53 c-ı | 3.30 f-k | 3.38 |
| $P_3Mg_2$ | 3.47 d-h | 3.77 a-d | 3.80 abc | 3.68 | 3.57 b-h | 3.83 abc | 3.67 b-f | 3.69 |
| Average | 3.06 | 3.39 | | 3.51 | 2.86 | 3.49 | 3.47 | |
| LSD (0.05) | 0.322 (Fertilizer levels × Irrigation treatments) | | | | 0.372 (Fertilizer levels × Irrigation treatments) | | | |

second year; the highest values were obtained from $I_3$ irrigation treatment and $P_1Mg_2$ and $P_3Mg_2$ applications in the first year, and from $I_3$ irrigation treatment and $P_2Mg_2$ application in the second year (Table 8). In the first year of the study, increasing water levels affected the number of seeds per pod increasing and increased it in the second year. Saadi and Yazdi-Samadi (1978) indicated that water and phosphorus jointly increased the number of seeds per pod. A field study by Muandemele et al. (1988) showed that aridity reduced the pod/plant, seed/pod ratio and the seed yield, and that exposure to aridity resulted in smaller seeds and reduced germination power in 30 soybean species.

Moreover, increasing phosphorus levels reduced the number of seeds per pod to a certain extent and magnesium levels increased it significantly in both years. Studies by Paikera et al. (1988) and Jayapaul and Ganasaraja (1990) reported that increasing doses of phosphorus considerably increased the number of seeds per pod in soybean plants. Bakaloglu and Aycicegi (2005) reported an average of 2.38 seeds per pod, while Karasu et al. (2002) reported a maximum of 2.14 seeds per pod,

**Table 8.** Mean number of seeds per pod and the groups determined at different irrigation levels and fertilizer combinations in 2006 and 2007.

| Fertilizer level | 2006 Irrigation treatment | | | Average | 2007 Irrigation treatment | | | Average |
|---|---|---|---|---|---|---|---|---|
| | $I_1$ | $I_2$ | $I_3$ | | $I_1$ | $I_2$ | $I_3$ | |
| $P_0Mg_0$ | 2.73 g-l | 2.60 jkl | 2.77 f-l | 2.70 | 2.00 k | 2.33 ij | 2.67 efg | 2.33 |
| $P_0Mg_1$ | 3.03 a-g | 2.97 b-ı | 3.03 a-g | 3.01 | 2.20 jk | 2.80 c-f | 2.80 c-f | 2.60 |
| $P_0Mg_2$ | 3.23 abc | 3.10 a-e | 3.27 ab | 3.20 | 2.33 ıj | 2.87 b-e | 3.07 ab | 2.76 |
| $P_1Mg_0$ | 2.57 kl | 2.60 jkl | 2.77 f-l | 2.64 | 2.33 ıj | 2.40 hıj | 2.60 fgh | 2.44 |
| $P_1Mg_1$ | 3.00 b-h | 2.73 g-l | 3.13 a-e | 2.96 | 2.53 ghı | 2.60 fgh | 2.73 d-g | 2.62 |
| $P_1Mg_2$ | 3.20 a-d | 2.93 c-ı | 3.33 a | 3.16 | 2.73 d-g | 2.80 c-f | 2.93 bcd | 2.82 |
| $P_2Mg_0$ | 2.67 i-l | 2.70 h-l | 2.53 l | 2.63 | 2.20 jk | 2.40 hıj | 2.63 e-h | 2.41 |
| $P_2Mg_1$ | 2.87 e-k | 2.90 d-j | 2.83 e-l | 2.87 | 2.33 ıj | 2.60 fgh | 2.80 c-f | 2.58 |
| $P_2Mg_2$ | 3.07 a-f | 3.13 a-e | 2.90 d-j | 3.03 | 2.73 d-g | 3.00 abc | 3.20 a | 2.98 |
| $P_3Mg_0$ | 2.67 ı-l | 2.73 g-l | 2.53 l | 2.64 | 2.53 ghı | 2.40 hıj | 2.20 jk | 2.38 |
| $P_3Mg_1$ | 2.90 d-j | 2.77 f-l | 2.87 e-k | 2.84 | 2.80 c-f | 2.60 fgh | 2.53 ghı | 2.64 |
| $P_3Mg_2$ | 3.23 abc | 3.03 a-g | 3.33 a | 3.20 | 2.93 bcd | 2.73 d-g | 2.93 bcd | 2.87 |
| Average | 2.93 | 2.85 | 2.94 | | 2.47 | 2.63 | 2.76 | |
| LSD (0.05) | 0.309 (Fertilizer levels × Irrigation Treatments) | | | | 0.253(Fertilizer levels × Irrigation Treatments) | | | |

which varied by species. The results of our study show some similarity with the aforementioned studies; the numbers of seeds per pod are generally in agreement with the values reported in the literature, and it was found that some fertilizer combinations produced an increase in our values.

## Conclusion

It was found that increased irrigation water and P and Mg applications increased soybean yields. The highest yield was obtained from $I_3$ irrigation treatment and $P_1Mg_2$ (564.50 kg $da^{-1}$) application in the first year of the study, and from the same irrigation treatment and $P_2Mg_2$ (533.57 kg $da^{-1}$) application in the second year. Low yield was obtained from the irrigation treatments in which water stress was applied. Application of Mg to the soil increased yields compared to the soya yields around world. It was concluded that Mg has an important role in increasing yields in conditions where the reduction of irrigation and fertilization is necessary. Increasing water, phosphorus and magnesium levels also increased the yield per decare, plant height, number of nodes, number of branches, number of pods and pod height. Increasing water also increased the first pod height while increasing phosphorus and magnesium levels decreased it. Moreover, increasing water level also increased the number of seeds per pod to some extent; increasing phosphorus levels decreased the number of seeds and increasing magnesium increased the number of seeds.

The soya bean is considered for inclusion in the crop rotation cycle with the start of irrigation in the Harran Plain. The results of this study demonstrate that high quality products could be obtained while conserving water and reducing fertilizer inputs. The results may be of use to producers and could inform further studies related to the cultivation of soya bean under the climatic conditions of the Northeast Anatolian region.

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