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GREEN PEA RESPONSE TO DEFICIT IRRIGATION RATES UNDER SEMI-ARID CLIMATIC CONDITIONS

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Abstract

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A study was carried out in the 2008 and 2009 cropping seasons, to determine the supplemental irrigation effect on yield and yield components of green pea under the semi-arid climatic conditions of Harran Plain, Sanliurfa, Turkey. Irrigation treatments included I_0 (dryland), I_{25}, I_{50}, I_{75}, I_{100} (full irrigation), and I_{125} (over irrigation) and scheduled based on soil moisture measurements. Annual precipitation was about 200 mm in first year and 275 mm in the second year. In addition, the full irrigation treatment plot received 235 and 195 mm in respective years. Almost all of the measured crop parameters including number of pod per plant, 1000- seed weight, biomass and seed yield parameters were increased by irrigation treatments up to full irrigation except number of branch as per plant. Biomass values ranged in general from 5500 (dry land) to 11500 (fully irrigated) kg ha^{-1}, while seed yield varied from 1300 (dry land) to 3450 (full irrigated) kg ha^{-1}. Therefore it is recommended to fully irrigate the green pea crop for optimum biomass and seed yield when irrigation water is available. Otherwise, considerable yield reduction can be anticipated.

Key yords: irrigation, Green pea, harvest index, seed yield.

Introduction

Green pea (*Pisum sativum*) contains high amount (about 30%) of protein, carbohydrate, calcium, iron, phosphorus and other vitamins. Therefore, it is very important agricultural commodity for human diet (Newman, 1988). In addition, green pea has positive effect on soil fertility through nitrogen fixation by the *Rhizobium leguminosarum* bacteria. Green pea cultivated areas in the world come third after the dry bean and the chickpea in legumes family. China is the biggest producer followed by India, while Turkey is ranked as 10th (FAO, 2013). Production in Turkey has a bigger potential for green pea production than with currently cultivated area (about 10 378 ha) and production value since the crop is native to the Asia and the Middle East.

Green pea plants usually have up to 8 cm tall 10 pods and the growing period may extend to 70 days (Sayre et al., 1953). On the other hand, Khvostova (1983) claimed that the green pea growing period may prolong up to 140 days.

In general, water stress during any stage of agricultural crops result in yield loss. Drought during the generative stages seems to substantially lessen the seed yield while any stress during the vegetative stages slows down plant development and shortens the growth period. Similarly, Acosta-Gallepos and Shibata (1989), Miller and Burke (1983), Singh (1995) and White and Izquierdo (1991) stated that water stress resulted in lowered yield, 1000 seed yield and shortened growing period.

Salter and Willianis (1967) stated that irrigation of green pea at the beginning of flowering and seed formation substantially increases seed yield. While Stock (1986) claimed that irrigation at the middle of the crop growing season may increase green pea seed yield by 700 kg ha^{-1}. Likewise, Marouelli et al. (1989) stated that with irrigation both green pea seed yield and quality increased. On the other hand, some morphological parameters of green pea were reduced with irrigation deficit (Acosta-Gallegos, 1988). In particular, water

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stress at the flowering stage substantially reduces green pea yield (Miller and Burke, 1983). Similarly, any water stress at flowering and green filling stages reduces yield (Singh, 1995) ranging 22 to 71% (Ramirez-Vallejo and Kelly, 1998).

Lorento et al. (1990) conducted a study in Spain to determine the effect of irrigation on green pea yield and reported average yield was 4660 kg ha^{-1}. Similarly, Deumier (1991) conducted as tudy in different locations in France while irrigations were performed before and after the flowering stages of the crop and resulted yield ranged from 5350 to 6350 kg ha^{-1}. On the other hand, Bailey and Groves (1992) conducted a study under the England conditions where they tested both dry land and irrigated farming of green pea and reported yields ranged from 1920 to 2660 kg $ha^{-1}$and from 3920 to 4500 kg ha^{-1} for Bohatyr and Solara varieties, respectively. Singla et al. (2006) claimed that the green pea yield was in average 6000 kg ha^{-1} under Punjab, India conditions. While, Zain et al. (1983) reported values ranging from 1150 to 4360 kg ha^{-1} under Lincoln, USA conditions and stated that deficit irrigation may result in 40% seed yield loss. Sayreet al. (1953) stated that green pea crop may produce as much as 5800 kg ha^{-1} depending on the variety.

The Southeastern Project (locally called GAP) is an economic and social integrated project with which about 1.2 million hectare of land will be opened to irrigation when completed. The original crop pattern in the project included different agricultural plants to be cultivated, unfortunately cotton and maize as a second crop in irrigated areas while wheat, barley and lentil dominate the pattern in dry land thus resulting in a fragile agricultural sector. Different options are being explored to diversify agricultural practices. One of the alternative crops is green pea as farmers are familiar with the cultivation of legume crops in the area and are therefore expected to easily adapt to green pea crop cultivation. Furthermore, green pea has a good economic value and can easily be used both green and dry. Therefore, the aim of the current study was to find out the effects of irrigation rate on yield and yield components of green pea.

Materials and Methods

The field experiments were conducted during the 2008 and 2009 crop growing seasons at Harran University (Turkey), Faculty of Agriculture experimental field with altitude 460 m, latitude 36° 42’ N and longitude 38° 58’ E. Average annual (average of two year) temperature 14.5^{0}C, relative humidity 53.5%, and solar radiation 447 cal cm^{-2} (Dogan et al., 2013) (Table 1). The experimental field had a clay loam soil

Table 1
Weather data of the study area, data from Dogan et al., 2013

Parameters	Months	Min. Air Temp., ^{0}C	Max. Air Temp., ^{0}C	Av. Temp., ^{0}C	Precipitation, mm	Relative Humidity, %	Solar Radiation, Cal cm^{-2}
2007 – 2008	November	2.2	26.8	12.5	15.4	58.1	252.0
	December	-2.0	16.1	6.8	45.6	65.5	195.1
	January	-3.2	13.5	3.7	57.1	52.2	230.1
	February	-3.1	17.5	6.6	28.3	59.9	316.4
	March	4.2	29.5	14.7	12.4	55.7	503.3
	April	6.0	36.4	20.4	1.8	48.0	608.1
	May	9.9	37.0	22.1	26.7	47.2	726.0
	June	17.8	42.3	29.8	8.6	29.8	797.7
	Average	4.0	27.4	14.6	24.5	52.1	453.6
2008 - 2009	November	6.0	24.7	14.0	35.3	62.3	255.4
	December	-1.7	19.5	7.0	37.7	58.6	199.3
	January	-4.7	15.7	5.7	29.8	59.1	213.9
	February	0.1	17.3	8.0	54.5	72.2	253.9
	March	1.5	23.0	10.0	55.3	65.6	460.1
	April	5.9	27.5	15.8	48.8	53.0	627.2
	May	10.0	37.0	22.7	4.7	36.3	755.8
	June	17.8	40.0	29.6	9.2	29.1	754.7
	Average	4.4	25.6	14.1	34.4	54.5	440.0

(Vertic Calciorthid Aridisol) with an average field capacity of 40%, a permanent wilting point of 22.1% resulting in available soil moisture of 77.3 mm from 90 cm soil depth with 13 mm h^{-1} infiltration rate. The hybrid Bolero was realized as a green pea cultivate due to its response in the region. Active root depth was assumed to be 90 cm for irrigation scheduling purposes.

Air temperature and solar radiation were slightly higher on the study region in 2008 than 2009, but overall climatic conditions were close to long term averages in both years. Solar radiation in 2008 and 2009 were 453 and 440 MJ m^{-2} day^{-1}, respectively, while average temperatures for the same years were 14.6 and 14.1^{0}C. On the other hand, 196 and 275 mm of precipitation were received during crop growing periods of the respective years (Table 1).

In order to prepare the seed bed, two soil cultivations were performed before sawing. Experimental trail plots were 6 x 2.4 m in size, and consisted of 6 rows with 40 cm between row and 5 cm on row spacing. The green pea seeds were hand sown in the trial plots (40 plants m^{-2}) with 20 kg ha^{-1} of pure (actual) nitrogen and phosphorus on November 19 and November 8 in 2007 and 2008, respectively. The middle four rows were hand harvested on May 24, 2008 and May 29, 2009, and the other two rows were considered as side effects.

The irrigation treatments were set as I_0 (dry land), I_{25}, I_{50}, I_{75}, I_{100} (full irrigation which brings the soil moisture to field capacity), and I_{125}(over irrigation).The purpose of using the over-irrigation treatment (I_{125}) was to determine the polynomial relationship between measured crop parameters and irrigation since such a relationship replicates better measured data. Soil water content of trial plots was measured gravimetrically twice a week and irrigations were scheduled accordingly. The soil water content prior to irrigations was sampled at 30, 60 and 90 cm layers. Irrigation scheduling was performed based on full irrigated treatment (I100), when the soil moisture reached 50% (± 5%) of the available water, irrigations were initiated. Treatment plots were irrigated with a drip irrigation system with 4 l h^{-1} emitter discharge. In the first year of the current study, 5 irrigations were performed including the 25 mm irrigation for germination on November 20, 2007. While in the second year, a total of 4 irrigations were made including 25 mm irrigation for germination on November 10, 2008. The first irrigations started in April for both of the study years. Green pea water use was calculated with the method suggested by Doorenbos and Kassam (1979).

$$ET = I + P - Dr - Rf \pm \Delta s \quad (1)$$

Where; ET is evapotranspiration (mm), I is irrigation water (mm), P is effective rainfall plus capillary rise (mm), Dr is drainage (mm), Rf is runoff (mm), and Δs is the change in moisture content (mm).

As there were no excess irrigations and runoff during irrigations, Rf and Dr were assumed to be zero making the equation to;

$$ET = I + P \pm \Delta s \quad (2)$$

The measured parameters included crop seed yield, above ground biomass, plant height, number of pods per plant, 1000 seed weight, and resulting harvest index (HI). The harvest index was calculated with the following equation.

$$HI = Yt / BM \quad (3)$$

In equations 3, Yt is the green pea seed yield (kg ha^{-1}), and BM is the above ground biomass (kg ha^{-1}).

The setup of the current study was complete randomized design with 3 replications. SPSS (2002) statistical program was utilized for statistical analysis. Variances among the main treatments (irrigations) were analyzed using ANOVA and regression tests and results were considered significant at $p < 0.05$ level.

Results and Discussion

In both study years high stress plots (I_0, I_{25}, and I_{50}) were harvested about 1 week earlier than I_{75}, $I_{100}$and I_{125}trials due mainly to water stress. In support, Xiao et al. (2007) indicated that with increased temperatures growth stages of many crops will be shortened. Irrigation treatment plots received higher irrigation amounts in 2008 than 2009 due to lower precipitation and higher temperatures in 2008. Full irrigated treatment plots received 235 mm and 195 mm of irrigation water in 2008 and 2009, respectively (Table 2).

Overall, water stress decreased green pea plant height which varied from 45 to 59 cm and from 46 to 58 cm in 2008 and 2009, respectively. Statistical analysis of the data indicated no significant ($p > 0.05$) plant height difference between the years. Moreover, plots exhibited similar heights in each stressed (I_0, I_{25} and I_{50}) and non-stressed irrigation treatments (I_{75}, I_{100}, and I_{125}) while statistically lower ($p < 0.05$) heights were obtained in the stressed irrigation treatments plots in both years (Table 2). This was simply attributed to both shorter growth period and lower available soil moisture in those trials. Similarly to current study results, Fidan (1999) reported green pea plant heights ranged from 55 to 85 cm, while Chatterjee et al. (1991) reported an average height of 50 cm. Regression analysis of plant height for both of the study years indicated a significant ($p < 0.05$) positive polynomial relationship between irrigation and plant height with high coefficient of determination (R2) values of 0.91and 0.95 for 2008 and 2009, respectively (Figure 1).This points to a strong relationship between available soil moisture content and plant height. In the current study every cm of irrigation water seemed to increase plant height by about 0.6 mm.

The number of branches per plant varied from 5 to 7.0 and 5 to 6 in respective years. Statistical analysis of the data

Table 2
Measured crop parameters and statistical results

Parameters Year		Irrigation Trails					
		I_0	I_{25}	I_{50}	I_{75}	I_{100}	I_{125}
Seasonal Irrigation Amount (I. mm)	2008	25	82.5	140	197.5	255	312.5
	2009	25	73.75	122.5	171.25	220	268.75
Plant Height, cm	2008	45_{a}	50_{ab}	52_{bc}	58_{cd}	59_{d}	56_{bc}
	2009	46_{a}	52_{a}	53_{ab}	58_{c}	57_{c}	55_{bc}
Number of Branch	2008	5_{a}	5_{a}	6_{a}	5_{a}	7_{a}	7_{a}
	2009	5_{a}	5_{a}	5_{a}	6_{a}	6_{a}	6_{a}
Number of Pod	2008	3_{a}	3_{a}	5_{ab}	10_{bc}	14_{c}	13_{c}
	2009	3_{a}	2_{a}	5_{ab}	12_{bc}	14_{c}	13_{c}
1000 seed weight, g	2008	224.8_{a}	235.2_{ab}	241.5_{abc}	251.0_{bc}	263.9_{cd}	267.3_{d}
	2009	204.7_{a}	229.5_{ab}	237.1_{bc}	238.2_{bcd}	254.2_{cd}	260.7_{d}
Biomass, kg ha^{-1}	2008	5490_{a}	6044_{b}	6745_{b}	10296_{c}	11697_{cd}	10553_{d}
	2009	6055_{a}	6598_{a}	7440_{b}	10250_{c}	11186_{d}	10824_{d}
Yield, kg ha^{-1}	2008	1507_{a}	1983_{b}	2181_{b}	2717_{c}	3484_{d}	3319_{d}
	2009	1272_{a}	1868_{b}	2155_{b}	2582_{c}	3107_{d}	3054_{d}
Harvest Index	2008	0.27	0.33	0.32	0.26	0.30	0.31
	2009	0.21	0.28	0.29	0.25	0.28	0.28
Irrigation Water Use	2008	60.3	24	15.6	13.8	13.7	10.6
Efficiency	2009	50.9	25.3	17.6	15.1	14.1	11.4

Values at the same rows followed by different letters are significantly different at 0.05 level.

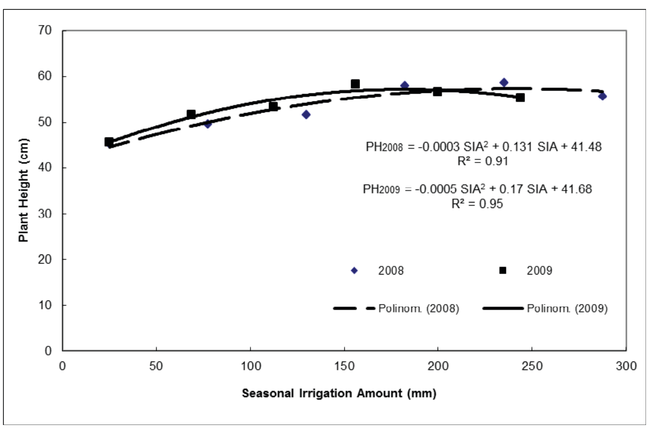

Fig. 1. Effect of seasonal applied irrigation and plant height for 2007-2008 and 2008-2009 seasons

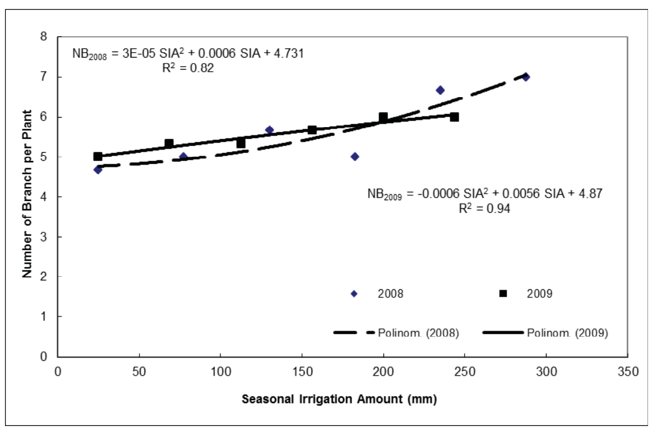

Fig. 2. Relationship between seasonal applied irrigation water and number of branch per plant for 2007-2008 and 2008-2009 seasons

did not detect significant differences among irrigation treatments (Table 2). The highest average occurred in the I_{100} and I_{125} trials, while, the lowest number of branches was obtained from I_0. It seems that water stress is not a factor determining the number of branches under the study conditions, even though regression analysis of the data indicated high R^2 values (0.82 in 2008 and 0.94 in 2009) for both of the study years (Figure 2). The number of pods per plant varied from 3 to 14 and statistical analysis of the data did not detect any significant difference between years. However, a strong significant ($p < 0.05$) effect of irrigation on number of pods per plant was detected (Table 2).

In parallel to our study results, Chatterjee et al. (1991) and Fidan (1999) reported an average number of pods per plant about while similarly Rasaei et al. (2012) noted that the number of pods per plant ranged from 12.5 to 18.5, which are close to our results. Statistical analysis of the data indicated that there were no differences within high stress plots (I_0, I_{25}, and I_{50}) and within fully irrigated trials (I_{75}, I_{100}, and I_{125}). Regression analysis also indicated a strong polynomial relationship between irrigation amount and number of pods per plant with high R^2 values of 0.89 and 0.84 for 2008 and 2009,respectively both of which were statistically significant ($p < 0.05$) 1 (Figure 3). Results indicated that over all every 10 mm of irrigation water resulted in additional 0.6 pod per plant.

Weights of 1000 seeds ranged from 224.8 to 263.9 g in 2008 while in 2009 the same values ranged from 204.7 to 254.2 (Table 2). In general, increased irrigation rates raised seed weights. Statistical analysis of the data indicated a significant difference within low irrigation treatments (I_0, I_{25}, and I_{50}) and high irrigation treatments (I_{75}, I_{100} and I_{125}). Moreover, there was an obvious statistical difference ($p < 0.05$) between high stress and fully irrigated treatments (Table 2). Regression analysis of 1000 seed weights as a function of irrigation water amounts indicated a significant ($p < 0.05$) polynomial relationship for both years with R^2 = 0.98 and 0.94 for 2008 and 2009, respectively (Figure 4).

The lowest biomass values in both study years were obtained from non-irrigated plots (I_0) as 5490 and 6055 kg ha^{-1} while the highest biomass values were observed in full-irrigated trials as11697 and 11186 kg ha^{-1} (Table 2). Rasaei et al. (2012) conducted a study in Iran on green pea and reported biomass values of 4753 kg ha^{-1} which is quite low compared to our study. Analysis of the biomass data did not detect significant difference within low irrigated treatments (I_0, I_{25}, and I_{50}) and fully irrigated ones (I_{75}, $I_{100}$and I_{125}). However, there was a significant ($p < 0.05$) biomass increase in I_{75}, I_{100} and I_{125} as compared to other water stressed treatments (I_0, I_{25}, and I_{50} in both of the study years) (Table 2). Moreover, regression analysis of the biomass data indicated a significant ($p < 0.05$) positive polynomial relationship between irrigation and biomass while equations for both of the years being Biomass 2008 = - 0.1016SIA^2 + 51.261SIA + 3426.9(R^2 20 = 0.69) and Biomass2009 = - 0.132SIA^2 + 55.3SIA + 4076.1 (R^2 = 0.742) for 2008 and 2009 respectively (Figure 5).

As expected, high stress irrigation trials produced yield values of 1507 and 1272 kg ha^{-1}while fully irrigated trials generated production values of 3484 and 3107 kg ha^{-1} in 2008 and2009, respectively (Table 2). In a study using Bolero green pea hybrid Fidan (1999) reported a yield value of 5789 kg ha^{-1} under irrigation conditions which is similar to our study result. Likewise, Jensen et al. (1985) determined the effect of irrigation on green pea yield and concluded that irrigation sub-

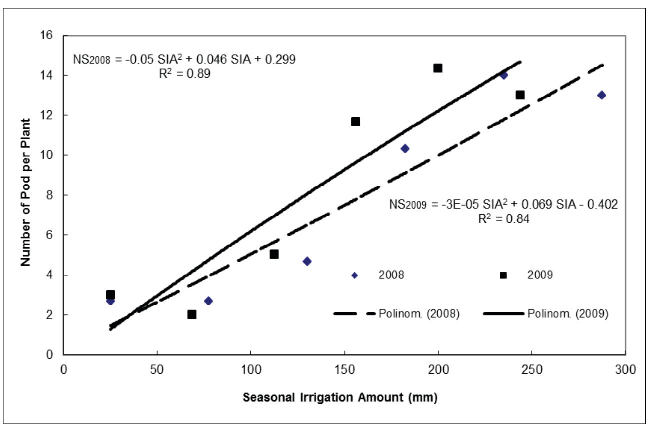

Fig. 3 . Seasonal applied irrigation effect on number of pod per plant for 2007-2008 and 2008-2009 seasons

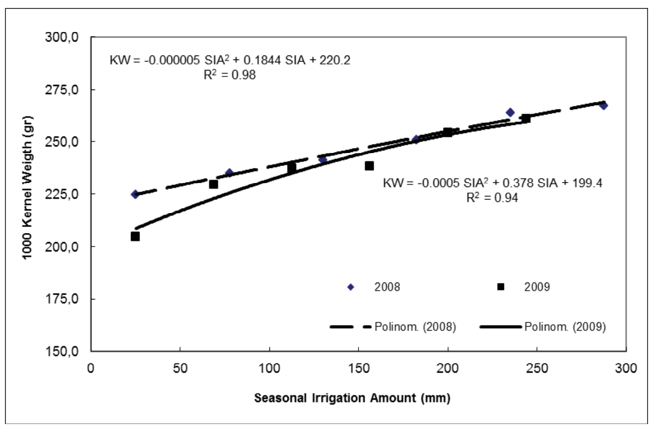

Fig. 4. Applied irrigation and 1000 seed weight for 2007-2008 and 2008-2009 seasons

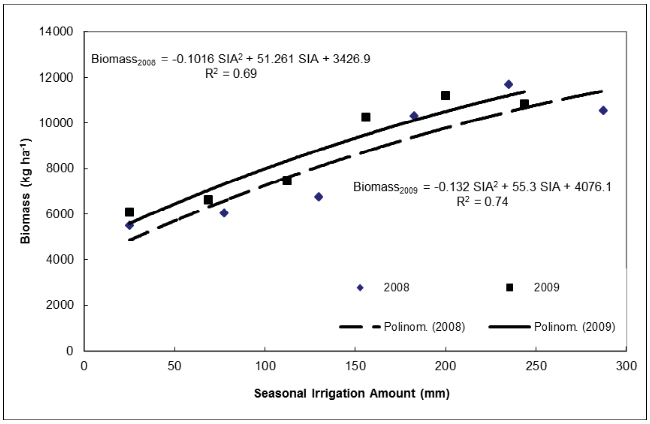

Fig. 5. Effect of irrigation on above ground biomass for 2007-2008 and 2008-2009 seasons

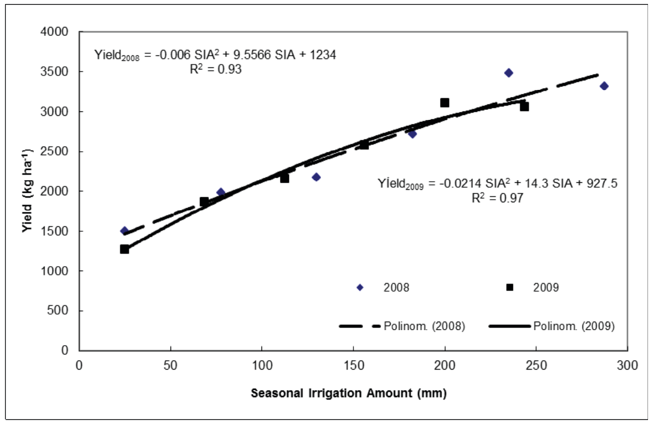

Fig. 6. Relationship between seasonal applied irrigation water and crop yield for 2007-2008 and 2008-2009 seasons

stantially increased yield. Reported yield values ranged from 2930 to 4370 kg ha^{-1} depending on the rate of irrigation which is in line with our data. Similar results were also reported by Zain et al. (1983) and Alan (1984). Rasaei et al. (2012) reported a maximum green pea yield value of 2160 kg ha^{-1} which is lower than our results. However in that experiment irrigation was applied only during flowering and pod development stages. Similarly, Singh and Yaday (1989) reported a maximum green pea value of 1840 kg ha^{-1} under no irrigation conditions while for Chatterjee et al. (1991) the highest yield was 2220 kg ha^{-1}. Our low yield values for stressed treatments clearly indicate the importance of irrigation under semi-arid climatic conditions. Statistical analysis of yield detected significant differences between treatments ($p < 0.05$) but not for different years (Table 2). In addition, regression analysis of yield values indicated high coefficient of determination (R^2) values of 0.98 for both years. Polynomial regression equations for 2008 and 2009 years were determined as Yield 2008 = 0.0239 SIA^2 + 2.729SIA + 1484.9 and Yield 2009 = - 9E - 05 SIA^2 + 10.04 SIA + 1068.9 both of which were statistically significant ($P < 0.05$) (Figure 6). Regression analysis of the data also indicated that for every 1 mm of irrigation green pea yield increased approximately 10 kg ha^{-1}.

The calculated harvest index (HI) values of the data did not indicate any distinct pattern but overall it seemed that with irrigations HI values decreased (not statistically significant) indicating that irrigation resulted in high development of crop canopy but not in yield. HI from both of the years varied from 0.21 to 0.33 which were parallel to reported values in the literature (Rasaei et al., 2012). Irrigation water use efficiencies (IWUE) in 2008 varied from 10.6 (I_{125}) to 60.3 (I_0)kg ha^{-1} mm^{-1} while for the same treatments IWUE values varied from 11.4 to 50.9 kg ha^{-1} mm^{-1}. In general, irrigation water as expected resulted in lower IWUE values in line with literature.

Conclusions

The current field study was conducted in the crop growing seasons of 2008 and 2009 to determine the effect of supplemental irrigations on green pea yield and yield components under semi-arid climatic conditions of Harran Plain, Sanliurfa, Turkey. Irrigation treatments included I_0 (dry land), I_{25}, I_{50}, I_{75}, I_{100} (full irrigation) and I_{125} (over irrigation) and irrigation events were scheduled based on the soil moisture measurements. Overall results from the current study noticeably indicated strong relationships between irrigation amounts and measured parameters which were plant height, number of pods per plant, and 1000 seed weight, above ground biomass and crop seed yield but not number of branches per plant. In general, increased irrigation amounts up to full irrigation significantly increased measured parameters. Depending on the amounts and time of precipitations, about 250 mm of supplemental irrigation would be enough for similar climatic condition for optimum crop development and seed yield. With no water stress, about3000 to 3500 kg ha^{-1} green pea yield may be expected under similar conditions. However, under dry land conditions, substantial yield reduction may be expected depending on the rate and the distribution of the precipitation.

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