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RESPONSE OF WHEAT CULTIVARS TO DIFFERENT LEVELS OF NITROGEN APPLICATION IN WATER DEFICIT CONDITIONS

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ABSTRACT

In order to study responses of two selected wheat cultivars to different water regimes and nitrogen application, this study was conducted at 2009-2010 in the research field of Karaj agricultural administration province, Iran. Wheat cultivars (*Triticum aestivum* L. cv. Gascogne and MV17) were selected as the experimental material. Treatment included: cultivars (Gascogne and MV17), three levels of nitrogen (0, 75 and 150 kg N ha^{-1}), and three levels of withholding irrigation I1: regular irrigation in total growth stages, I2: withholding irrigation at anthesis stage, and I3: withholding irrigation at seed filling period stage. At the end of growth season, five plants were selected randomly from each plot and number of spike per meter square, number of grain per spike, and 1000- seed weight, economic and biological yield were determined. The results showed that Nitrogen fertilizer application made significant effects on number of spike per meter square, economic yield, biological yield and harvest index (P<0.01). But number of grain per spike, and 1000- grain weight unaffected by nitrogen applied. In the other side, irrigation regimes had significantly effects on all of evaluated traits at 1% levels. The effects of nitrogen rates and irrigation regimes showed that Grain yield, increased with the gain of N rate (by 25.8% at N75 and by 55.9% at N150 compared with N0) and decreased with the increase of water stress during growth stages (by 14.5% at withholding irrigation at anthesis stage and by 40.6% at withholding irrigation at seed filling period compared with regular irrigation)

Keyword: Anthsis stage, Irrigation withholding, Nitrogen fertilization, Seed filling period, Wheat

INTRODUCTION

Adequate amounts of nitrogen and irrigation is required for normal growth of wheat. Nitrogen has an important role in the growth and development of wheat, and should be available for wheat in all of growing season. Also, wheat is an irrigated crop; its production is frequently exposed to water deficits at any stage of the crop development. Drought occurs in almost all climatic regions, and is a normal, temporary, and recurring feature of climate **[1]**. Wheat in Iran is grown entirely under irrigation during the short dry and comparatively cool winter season that extends from October to July and also High temperatures prevail during the end of the cropping cycle. The severity of a drought can be aggravated by high temperatures, high winds, and low relative humidity. **[2]** Defined water stress as the lack of amount of soil water that needed for plant growth and development which affect various metabolic processes. On the other hand, Drought can be defined as higher evaporation demand than precipitation or irrigation into soil. When higher plants were exposed to drought stress, plants use various mechanisms to cope with drought stress for their survival **[3]**. Nutritional status is very important for crop resistance to drought stress. Therefore, this experiment was performed to evaluated responses of two selected wheat cultivars to different water regimes and nitrogen application.

MATERIALS AND METHODS

Wheat cultivars (*Triticum aestivum* L. cv. Gascogne and MV17) were selected as the experimental material. This study was conducted at 2009-2010 in the research field of Karaj agricultural administration province, Iran. Treatment included: cultivars (Gascogne and MV17), three levels of nitrogen (0, 75 and 150 kg N ha^{-1}), and three levels of withholding irrigation (I1: regular irrigation in total growth stages, I2: withholding irrigation at anthesis stage, and I3: withholding irrigation at seed filling period stage). The quantity of irrigation water in each plot was calculated, controlled by counter and exercise irrigation treatments at different growth stages. The field experiments were laid out in split split plot based on Randomized Complete Block Design with three replications. At the end of growth season, five plants were selected randomly from each plot and number of spike per meter square, number of grain per spike, and1000-seed weight were determined. 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 economic yield. To determine biological yield, total plant dry weight was employed as biological yield, Harvest index was obtained by dividing economic yield by biological yield multiplied by 100. Data for evaluated traits were statistically analyzed using a standard analysis of Variance technique for the split spit plot in randomized complete block design. Means were separated by using Duncan's Multiple Range Test (DMRT) at 5 percent probability level.

Results and Discussion

The results of analysis of variance were shown in **Table 1**. Nitrogen fertilizer application made significant effects on number of spike per meter square, economic yield, biological yield and harvest index (P<0.01). But this treatment had no effect on number of grain per spike, and 1000- grain weight. On the other side, irrigation regimes had significantly effects on all of evaluated traits at 1% levels. Results of analysis variance were shown that responses of cultivars to nitrogen application were different under irrigation treatments. Number of spike per meter square was influenced by increased N applications **(Figure 1 A)**. Increasing the rate of N fertilization from 0 to 75 and 150 kg N ha^{-1} has stimulated the production of additional number of spike per m^2 by 29.6% and 71.1%, in comparison with check treatment (0 kg N ha^{-1}). Averaged across years and N treatments, number of spike per meter square was observed to increase in cultivar Gascogne by 34.9% and 75.5% in 75 and 150 kg N ha-1 treatments, in comparison with check treatment (330.7spike per m^2). Moreover, N fertilization of 75 and 150 kg N ha^{-1} has increased significantly (P < 0.01) number of spike per unit area in cultivar MV17 by 46.1% and 96.0%, compared to N fertilization of 0 kg ha^{-1} (249.7 spike per m2) **(Figure 2 A)**. In all the two growing seasons, number of spike per m2 in Gascogne cultivar is higher than the MV17 (454.8 and 450.0 in Gascogne compared with 385.6 and 380.3 in MV17 at 2009 and 2010, respectively) **(Figure 2 C)**. On the contrary, mean number of spike per meter square of irrigation regular treatment was 505.6 spikes per m2 and were 73.0 and 190.8 spikes per m^2 higher than withholding irrigation at anthesis and seed filling period stages, respectively **(Figure 1 B)**. However, the magnitude of the differences between the irrigation treatments was observed to be smaller in MV17 than in Gascogne. Indeed, while for cultivar Gascogne average increases in number of spike per m2 in response to regular irrigation were 97.7 and 219.7 in withholding irrigation at anthesis and seed filling period, respectively, compared to regular irrigation, the increases in the same treatments for cultivar MV17 were 48.3 and 161.8. This may reflect a higher aptitude of cultivar MV17 to water supply than cultivar Gascogne **(Figure 2 B)**. Partitioning and translocation of assimilates is dependent to water availability in soil **[4]**. Thus, crop yield reduce due to disorder in partitioning and translocation of assimilates **[5]**. Spike and grain number per plant are correlated with assimilates transport from the source into sink **[6]**. Regular irrigation was observed to increase grain number per spike in the all two growing seasons. Therefore, decrease in number of grain per spike were 13.2% and 5.3% in withholding irrigation at anthesis and seed filling period, respectively. Based on results obtained, water stress at anthesis stage had the most effects on number of grain per spike than the withholding irrigation at seed filling period **(Figure 3 B)**. **[7]** Concluded that spikelets per spike were more sensitive to drought stress in different wheat cultivars. Also, Spikelet and kernel number are affected by water stress occurs during the stem elongation stage **[8]**. Water stress at anthesis reduces pollination and thus less number of grains is formed per spike which results in the reduction of grain yield **[9]**. For cultivar Gascogne, the number of grain per spike were recorded 33.89 (2009) and 33.44 (2010) and for MV17 cultivar these amount were 39.22 (2009) and 37.63 (2010) **(Figure 3 C)**. Whereas, with nitrogen application, number of grain per spike increased 1.9% and 7.1% in 75 and 150 kg N ha^{-1}, respectively, compared with 0 kg N ha^{-1} **(Figure 3 A)**. In contrast, the 1000-grain weight seemed to be less affected than number of grain per spike for both cultivars by irrigation treatments and nitrogen rate **(Figure 4 A and B)**. **[10]** Also recorded that higher nitrogen application under drought stress resulted in lower grain weight in wheat. Moreover, data analyses for the 2-year experiment showed that nitrogen fertilization up to 75 kg N ha^{-1} had no significantly effects on 1000-grain weight, but with 150 kg N ha^{-1} application compared 0 kg N ha^{-1} (check treatment), 1000-grain weight 0.38% increased **(Figure 4 A)**. Also, nitrogen fertilization had no significantly effects on 1000-grain weight in all two cultivars **(Figure 5 A)**. The percentage of increase of 1000-grain weight in cultivar MV17due to regular irrigation was 5.8% compared with water stress at seed filling period, while no increase was observed in regular irrigation comparison with withholding irrigation at anthesis stage (44.00 g) **(Figure 5 B)**. Drought at critical stages of anthesis and grain filling has a detrimental effect on grain filling and quality traits **[11 and 12]**. Higher 1000 grain weight with full irrigations might be due to the more translocation of photosynthats towards grain due to the sufficient amount of water in root zone. Similar results were recorded by **[13 and 14]**. Translocation of dry matter to grain is negatively affected by the drought after the flowering stage **[14]**. For Gascogne cultivar, regular irrigation increased 1000-grain weight 0.66% and 4.46% compared with water stress at anthesis and seed filling period, respectively. **[15]** Also found negative effect of water stress on thousand kernel weight after the flowering stage in wheat. In the two growing seasons, For cultivar MV17, even though the weight of 1000-grain was slightly higher than for cultivar Gascogne, the magnitude of increase of 1000-grain weight in response to regular irrigation was observed smaller than in cultivar MV17 **(Figure 5 C)**. Water deficiency significantly reduces the final grain weight per ear and yield **[16]**, but enhances the remobilization of pre stored carbon reserves in source organs, such as leaves, to sink organs, such as grains **[16]** and roots **[17]**. Primary effects of nitrogen rates and irrigation regimes showed that Grain yield, increased with the gain of N rate (by 25.8% at N75 and by 55.9% at N150 compared with N0) and decreased with the increase of water stress during growth stages (by 14.5% at withholding irrigation at anthesis stage and by 40.6% at withholding irrigation at seed filling period compared with regular irrigation) **(Figure 6 A and B)**. **[13]** Reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. Water shortage is often associated with high temperatures that are known to shorten the duration of grain growth and to reduce the yield **[18]**. In our study, high-N applied had higher grain yield compared to unfertilized ones, as N deficiency reduced crop yield and plant storage capacity. Water stress during grain filling greatly reduced grain yield, and the yield reduction resulted from a little decrease of the number of grain per spike and a great decrease of mean grain weight. **[19]** Found that drought reduced grain yield due to a reduction in kernel growth rate, whereas **[20]** demonstrated that kernel size, and thus yield reduction, was due to the shortening of the duration of grain filling. At different Nitrogen treatments, there were 29.5% and 62.6% grain yield increases in Gascogne with N75 and N150 treatments, respectively, and 22.3% and 49.6% grain yield increases in MV17 with N75 and N150 treatments, respectively, when comparing with N0 (check treatment) **(Figure 7 A)**. In the other side, grain yield decreased with water stress in all two cultivars. Increase in grain yield with increasing irrigation frequency and N rate have also been reported **[21]**. Gascogne yield due to water stress reduced and from 8426 kg ha-1 reach to 6949 kg ha^{-1} in water stress at anthesis stage and 4910 kg ha^{-1} with withholding irrigation at seed filling period. Negative effect of drought on wheat yield has been presented in several studies **[14 and 22]**. Response of MV17 cultivar was similar to Gascogne. The grain yield of MV17 from 8358 kg ha^{-1} at regular irrigation declined and reaches to 7398 kg ha^{-1} in water stress at anthesis stage and 5065 kg ha^{-1} with withholding irrigation at seed filling period **(Figure 7 B)**. **[23]** Studied 68 wild wheat genotypes and reported that the tolerance level of wheat plant to the post anthesis drought was mostly regulated by the translocation capacity of dry matter to grain. Increase in grain yield with increasing frequency of irrigation has also been reported by **[24 and 25]**. But these results were differed with results obtained by **[26]** that concluded grain yield of different wheat cultivars were significantly reduced by water stress at all critical growth stages and greatest reduction was at anthesis stage. Interaction effects between irrigation regimes and N rates were shown that under well-watered and withholding irrigation at anthesis stage conditions, grain yield were increased in the high-N treatment (150 kg N ha-1) as compared to the low-N treatment (0 and 75 kg N ha-1) **(Figure 8 A)**.This results indicated that nitrogen use efficiency was higher in irrigated plants and/or plant stressed at anthesis stage than that of plants exposed to water stress during grain filling period. The results of our study showed that the highest grain yield was obtained with MV17 cultivar in all of two growing seasons **(Figure 8 B)**. Responses of biological yield to nitrogen fertilizer application and different irrigation regimes were similar to grain yield. The data revealed that with 75 and 150 kg N ha^{-1} compared 0 kg N ha-1 (check treatment) biological yield increased by 24.3% and 39.0%, respectively **(Figure 9 A)**. Moreover, withholding irrigation at anthesis and seed filling period increased biological yield by 11.5% and 29.7%, respectively **(Figure 9 B)**. Biological yield reduced from 16670 kg ha-1 in regular irrigated plants to 14750 kg ha-1 in withholding irrigation at anthesis stage and to 11710 kg ha-1 in withholding irrigation at seed filling period. Indeed, Effects of drought was dependent on the phonological stage of the wheat plants. It was observed that biological yield is varied with the application of different nitrogen levels in the two cultivars **(Figure 10 A)**. On the other hand, the response of Gascogne cultivar to nitrogen application from 75 to 150 kg ha-1 was lower than the MV17. While, nitrogen application up to 150 kg ha-1 resulted by 17.0% increase in biological yield of MV17 cultivar, but this increase for Gascogne was only by 6.5%. In contrast, biological yield reduction in Gascogne cultivar due to water stress was lower than MV17 **(Figure 10 B)**. The results of these experiments showed that different irrigation regimes and nitrogen treatments significantly affected the harvest index **(Figure 11 A and B)**. In both years, response of harvest index was more obvious with treatment where three irrigations were applied. Indeed, harvest index was affected more by irrigation treatment than Nitrogen application, Although, Both factor reduced the harvest index **(Figure 11 A and B).** Wheat plants regular irrigated were having significantly more harvest index as compared to all other treatments. **[27]** Reported that harvest index of the crop is significantly reduced due to water stress. Irrigation omitted at seed filling period resulted in minimum harvest index **(Figure 11 B)**. Moreover, MV17 cultivar had the highest harvest index at N0 treatment, but in continued, with increase in nitrogen application; harvest index was reduced, severely. Therefore, in MV17 cultivar, harvest index decreased from 45.63% in N0 to 40.77% and 39.32% by N75 and N150, respectively **(Figure 12 A)**. In contrast, nitrogen application up to 150 kg N ha-1 had slightly effect on harvest index **(Figure 12 B)**. The response of harvest index in evaluated cultivars to irrigation treatments varied from 45.84 to 43.03% in Gascogne, and from 44.93 to 39.04% in MV17 cultivar **(Figure 12 B)**. Harvest index for various cultivars differed significantly. The cultivar Gascogne 2009 and 2010 had 3.07% and 1.92% higher harvest index respectively with regard to MV17 **(Figure 12 C)**.

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Table 1: Analysis of variance of evaluated traits in wheat cultivars

				MS			
Source of variation	**d.f**	**NS**	**NGS**	**TGW**	**EY**	**BY**	**HI**
Year (Y)	**1**	**675.00**	**28.00**	**35.59**	**542300.08**	**19551725.03**	**2.22**
Cultivar (V)	**1**	**130208.33****	**611.56****	**35.59***	**866002.23**ns	**51181713.92****	**167.50***
Y×V	**1**	**1.33**ns	**8.89**ns	**4.48**ns	**49708.23**ns	**45387.00**ns	**8.84**ns
Error a	**4**	**1482.77**	**2.73**	**3.62**	**860244.42**	**1590261.17**	**16.86**
Nitrogen (N)	**2**	**448607.25****	**4.73**ns	**0.25**ns	**81656381.67****	**196469824.45****	**117.95****
Y×N	**2**	**978.25**ns	**4.34**ns	**3.59**ns	**330128.86**ns	**5648410.62***	**20.18**ns
V×N	**2**	**7746.08****	**9.23**ns	**0.25**ns	**207741.56**ns	**6622548.34***	**81.32****
Y×V×N	**2**	**731.08**ns	**2.39**ns	**0.48**ns	**138339.00**ns	**454535.02**ns	**4.41**ns
Error b	**8**	**716.02**	**4.56**	**2.78**	**117697.74**	**985027.87**	**5.07**
Irrigation (I)	**2**	**333477.75****	**235.73****	**100.25****	**107150666.28****	**225786600.06****	**170.49****
Y×I	**2**	**1075.75**ns	**2.00**ns	**0.25**ns	**129556.02**ns	**1230539.23**ns	**28.46****
V×I	**2**	**8776.08****	**8.39**ns	**10.25**ns	**604822.95***	**6253456.39****	**21.27****
Y×V×I	**2**	**144.08**ns	**5.89**ns	**1.81**ns	**221387.50**ns	**891872.52**ns	**4.94**ns
N×I	**4**	**12925.87****	**4.60**ns	**2.17**ns	**3963679.17****	**14510051.87****	**3.33**ns
Y×N×I	**4**	**437.37**ns	**5.96**ns	**0.50**ns	**142643.05**ns	**152439.14**ns	**9.60***
V×N×I	**4**	**881.20**ns	**25.69***	**3.17**ns	**306084.12**ns	**1318381.23**ns	**7.93**ns
Y×V×N×I	**4**	**277.20**ns	**1.27**ns	**2.06**ns	**32566.87**ns	**657126.30**ns	**4.50**ns
Error c	**24**	**670.94**	**6.53**	**6.56**	**174249.16**	**723362.23**	**2.91**
Error	**32**	**320.01**	**8.08**	**5.66**	**53222.97**	**812366.66**	**4.49**
Coefficient of variation (%)	**-**	**4.28**	**7.89**	**5.61**	**3.37**	**6.27**	**4.92**

-ns, * and **: non-significant, significant at 5% and 1% levels of probability, respectively

-NS: Number of spike per meter square, NGS: Number of grain per spike, TGW: 1000-grain weight (gr), EY: Economic yield (kgha^{-1}), BY: Biological yield (kgha^{-1}) and Hi: Harvest index (%)

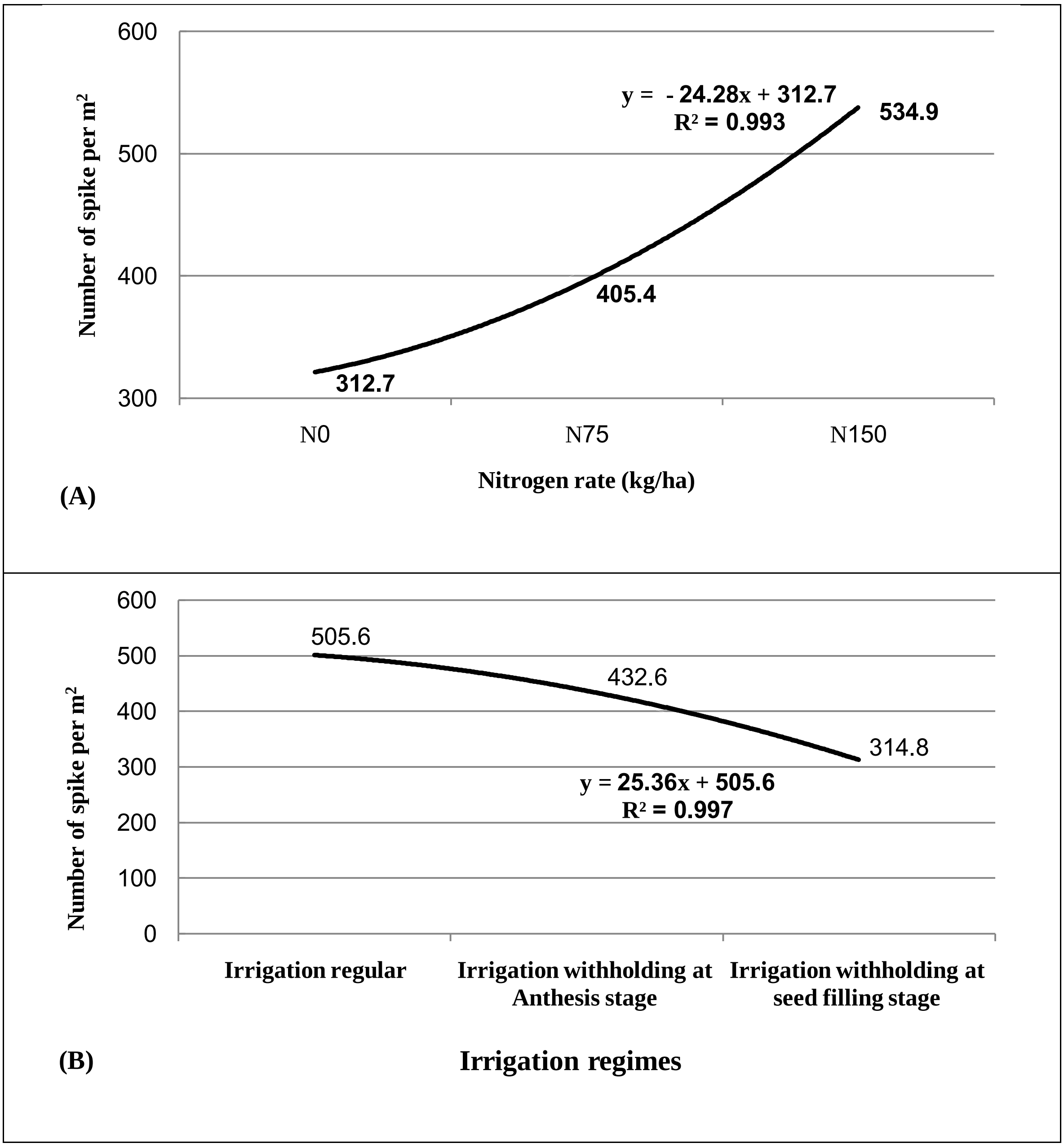

Figure1: Response of number of spike per meter square in nitrogen application (A) and irrigation treatments (B)

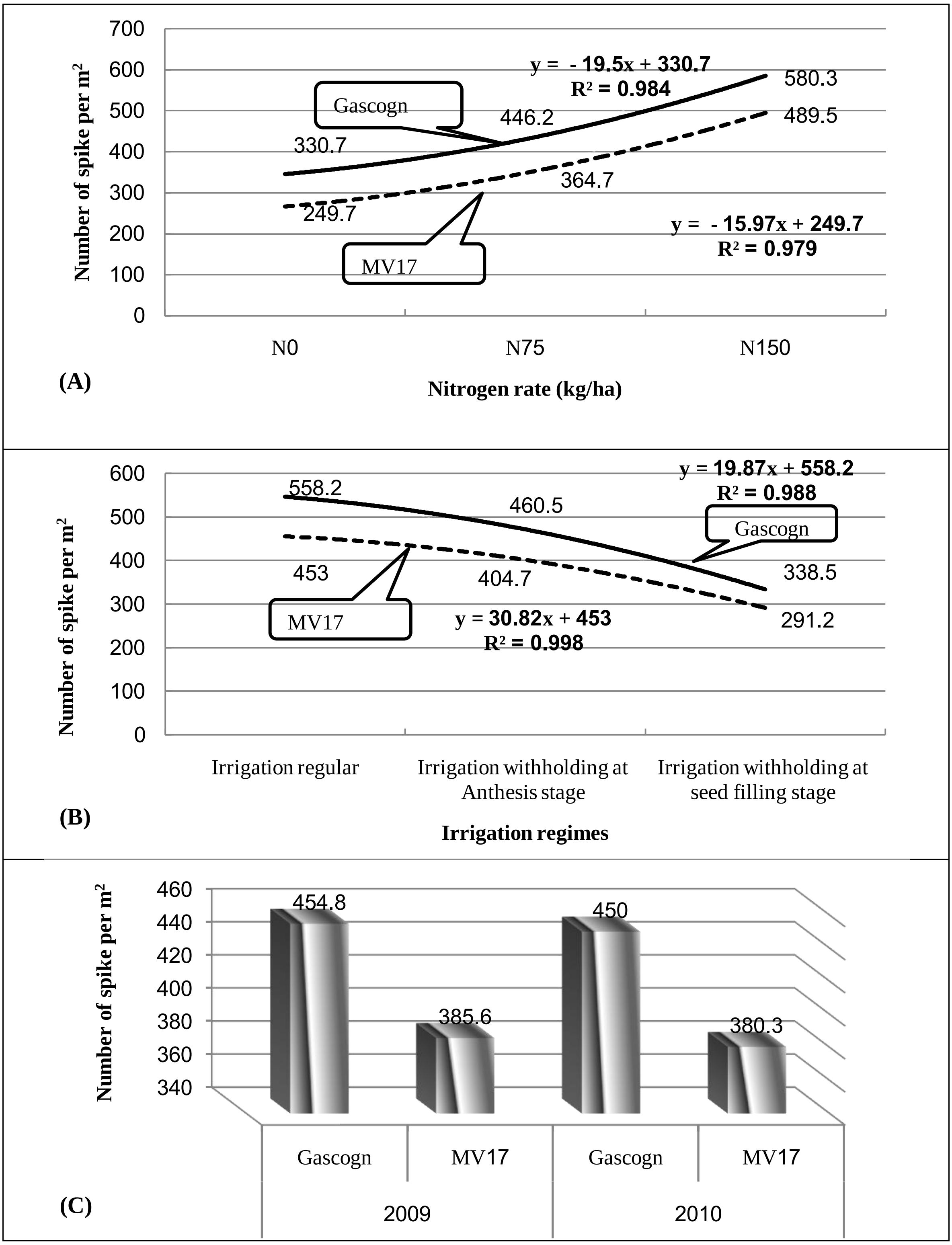

Figure 2: Changes in number of spike per meter square in wheat cultivars affected by nitrogen application (A), irrigation regimes (B) in both years (C)

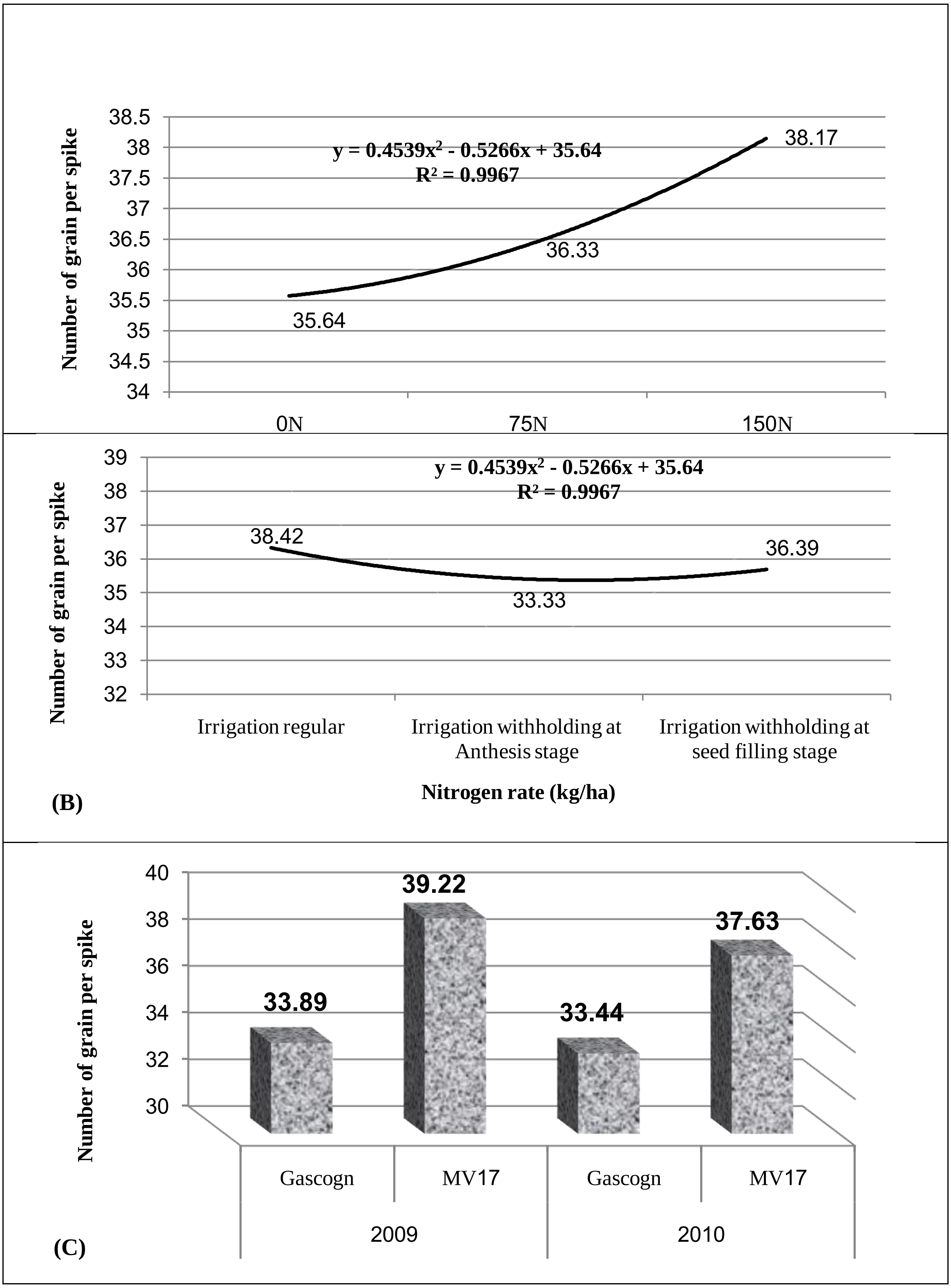

Figure 3: Changes in number of grain per spike affected by nitrogen application (A), irrigation regimes (B) and wheat cultivars at both years (C)

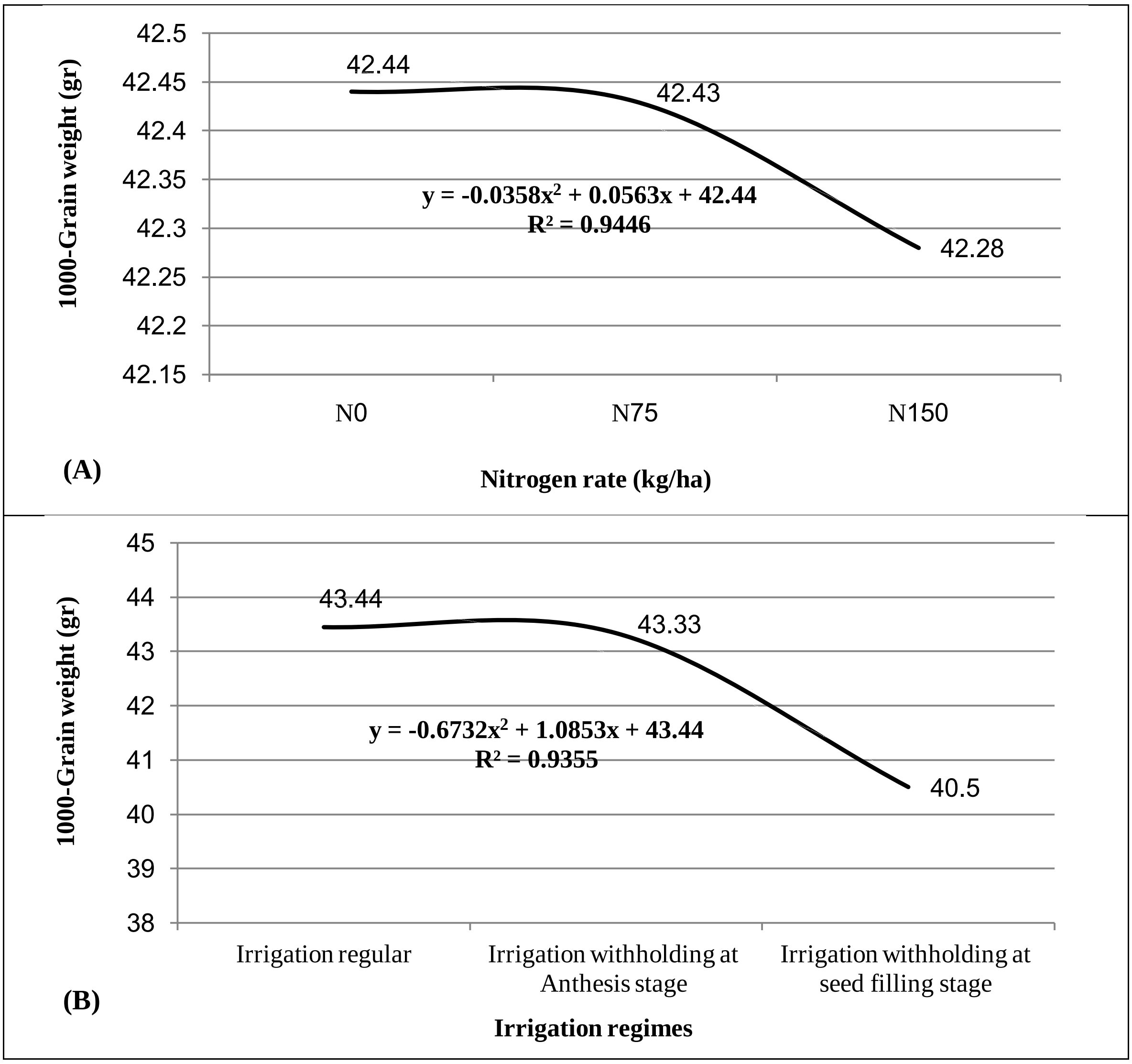

Figure 4: Response of 1000-grain weight to nitrogen application (A) and irrigation regimes (B)

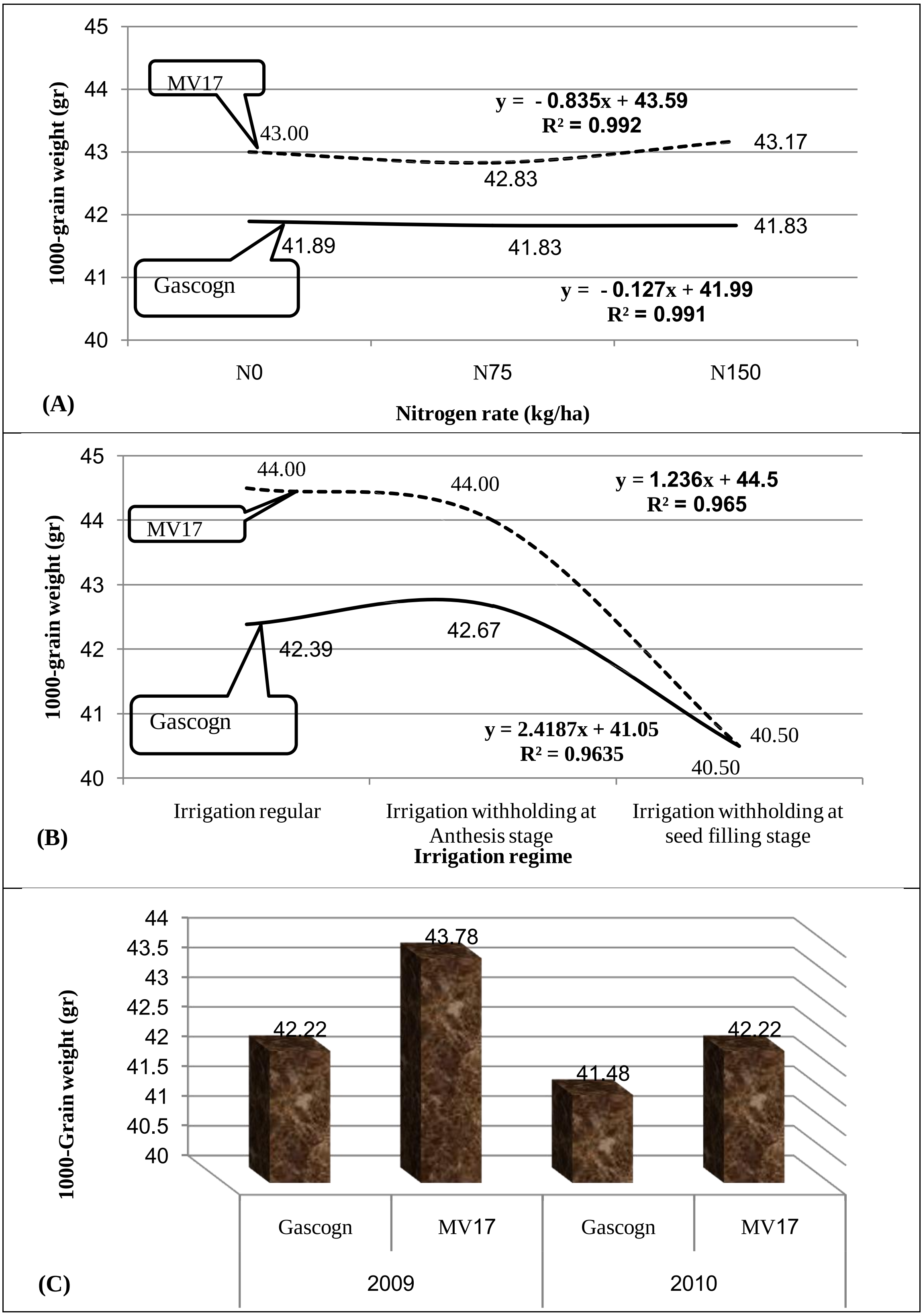

Figure 5: Changes in 1000-grain weight in wheat cultivars affected by nitrogen application (A), irrigation regimes (B) in both years (C)

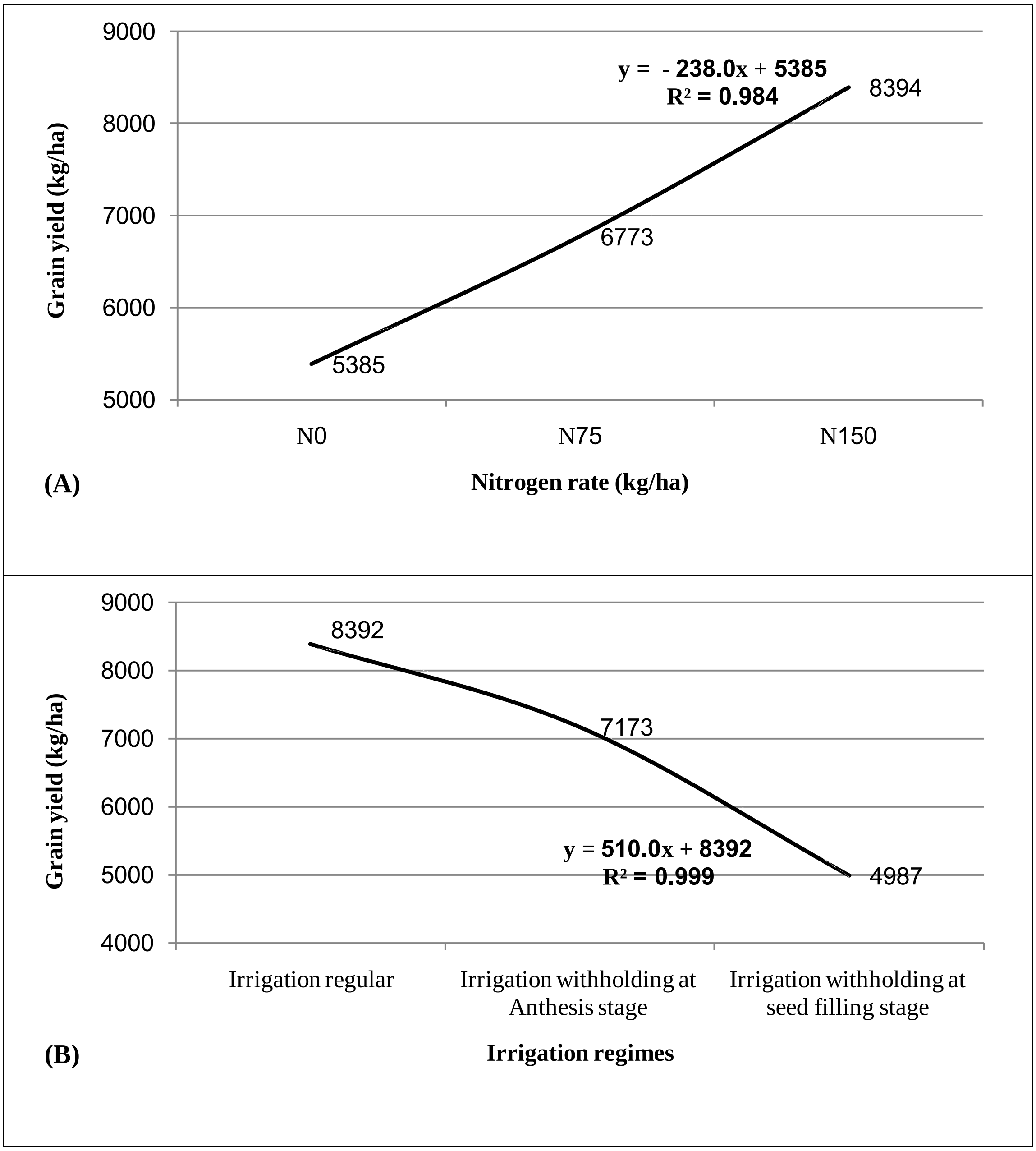

Figure 6: Response of wheat grain yield to nitrogen application (A) and irrigation regimes (B)

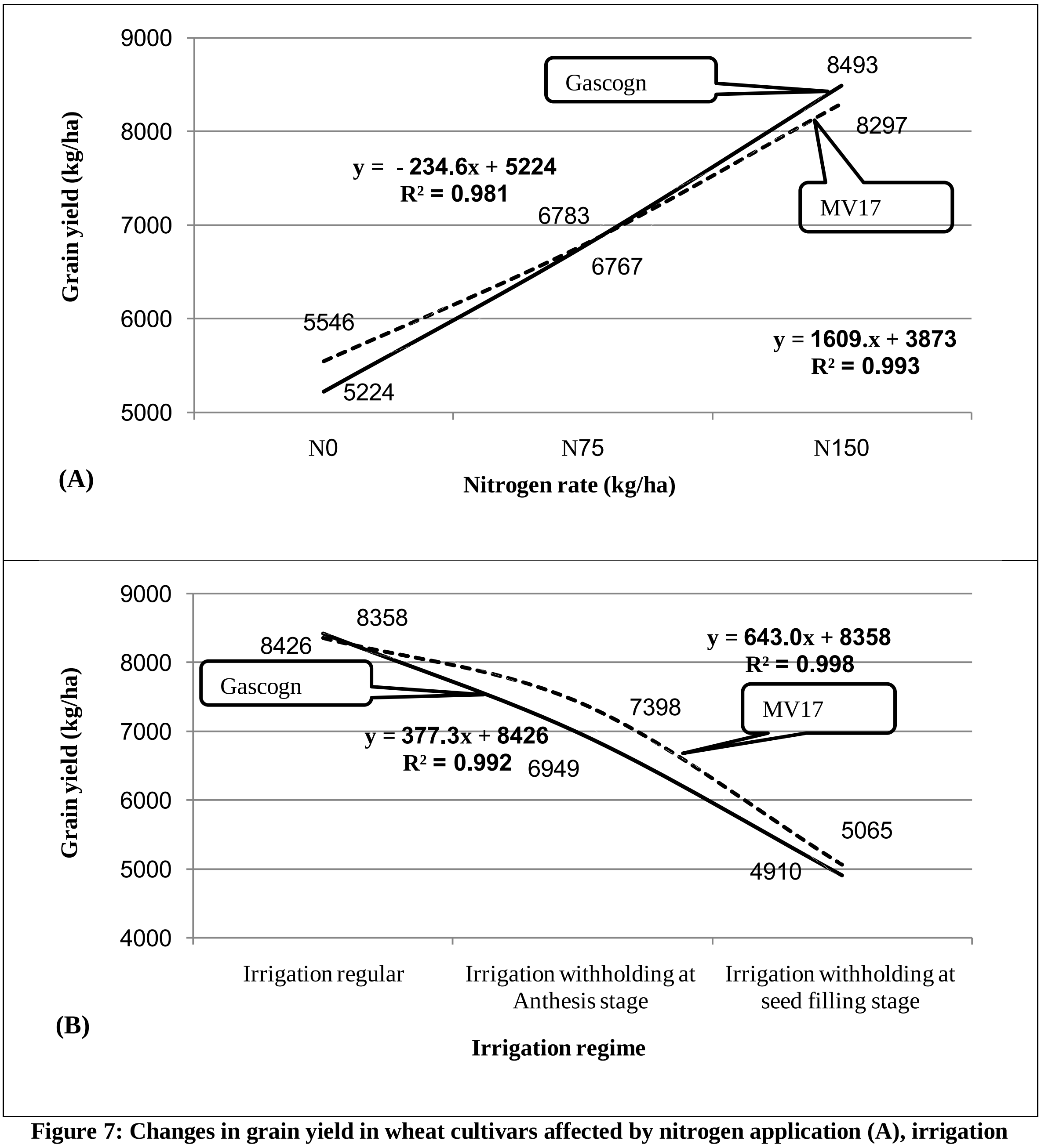

Figure 7: Changes in grain yield in wheat cultivars affected by nitrogen application (A), irrigation regimes (B)

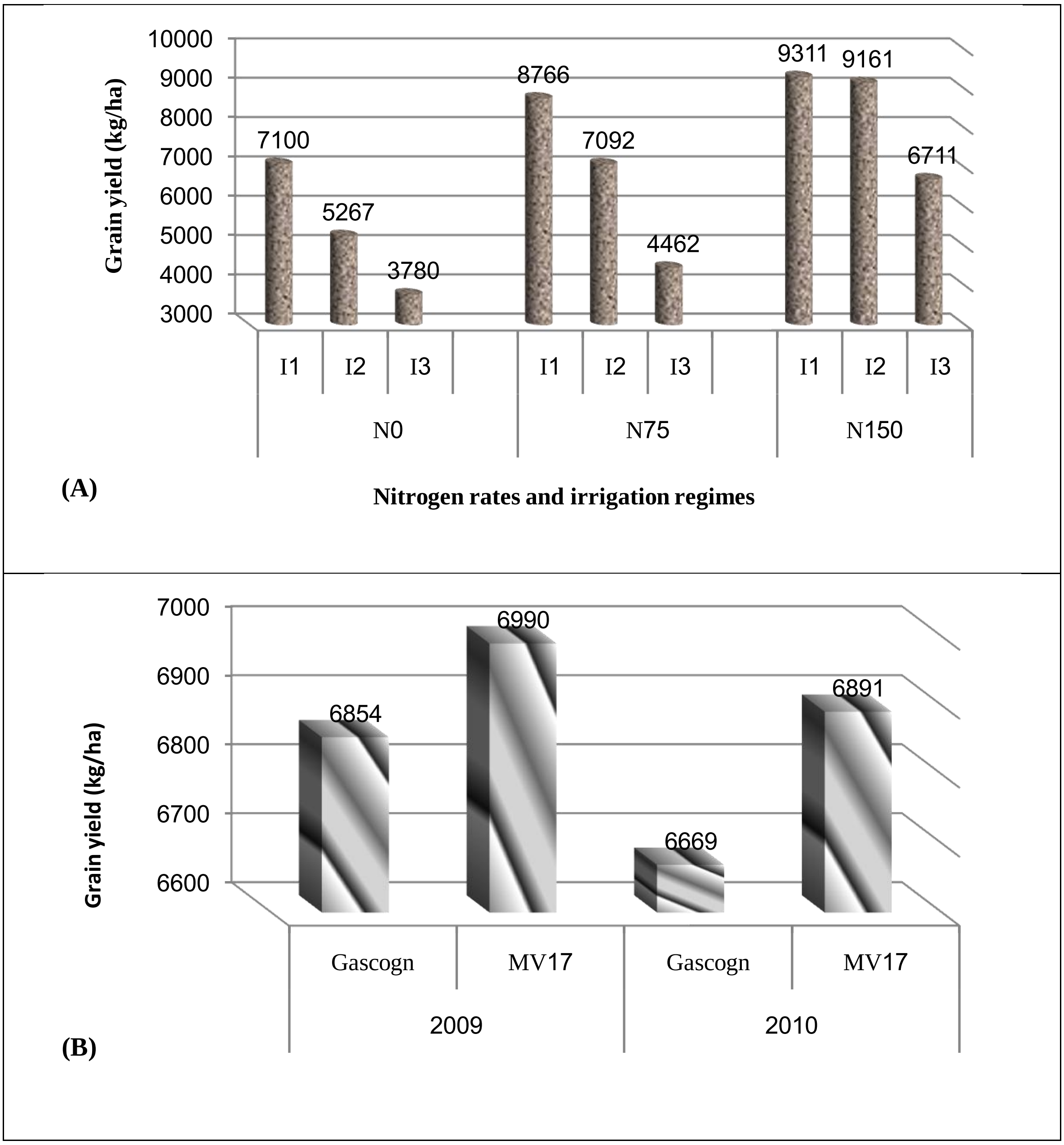

Figure 8: Grain yield affected by nitrogen application and irrigation regimes interaction (A) and wheat cultivars in both years (B)

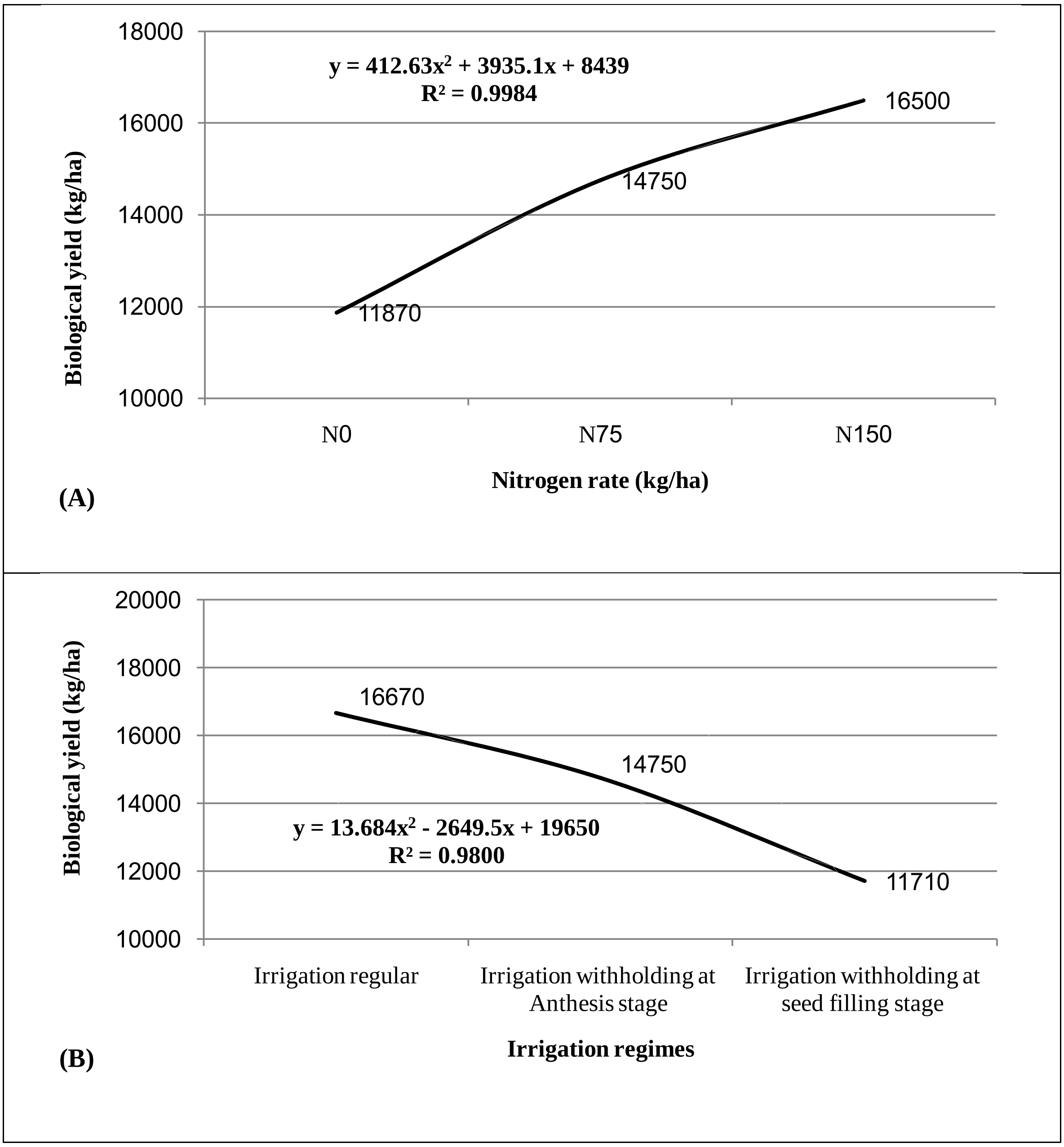

Figure 9: Response of biological yield to nitrogen application (A) and irrigation regimes (B)

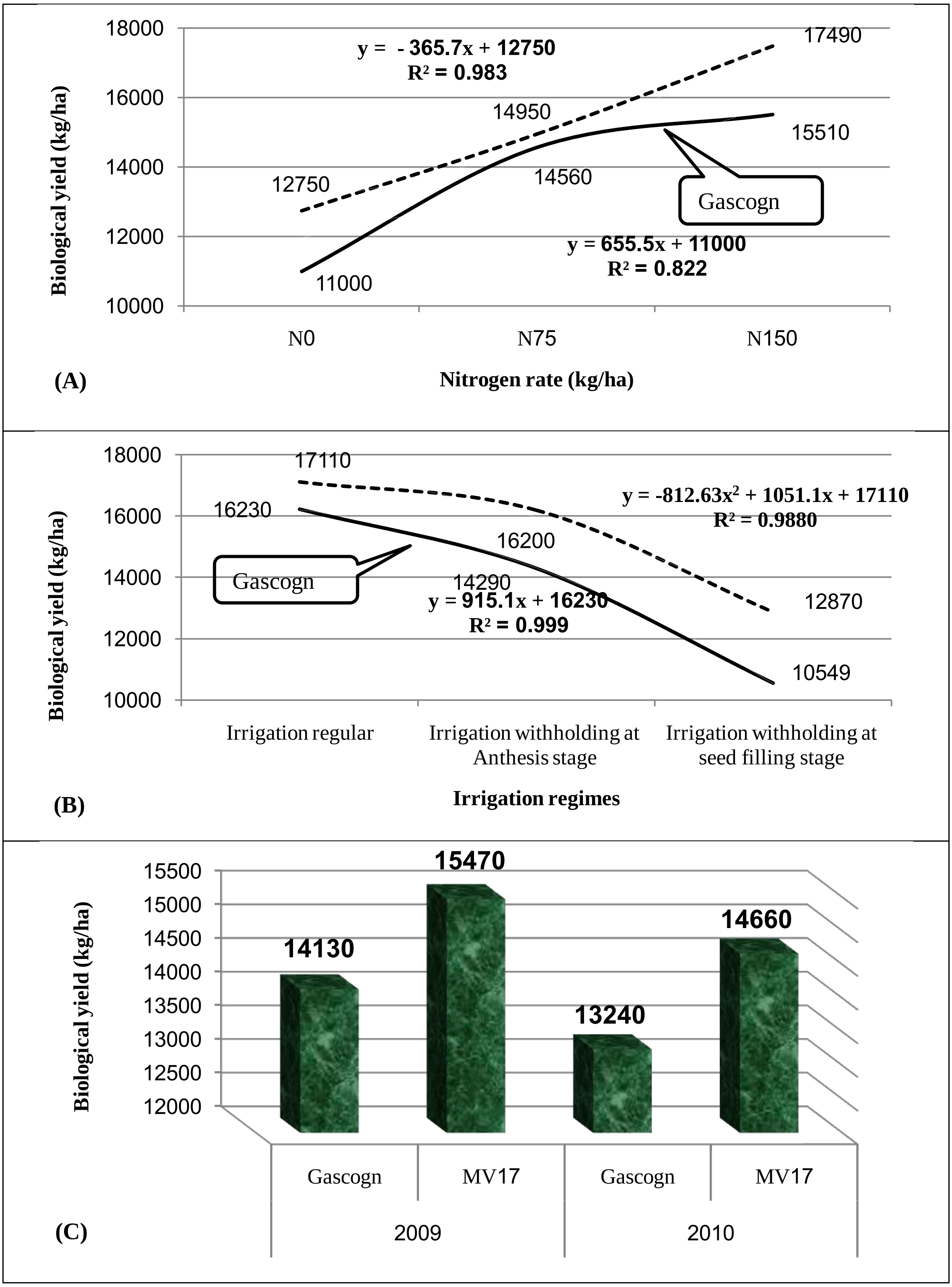

Figure 10: Changes in biological yield in wheat cultivars affected by nitrogen application (A), irrigation regimes (B) in both years (C)

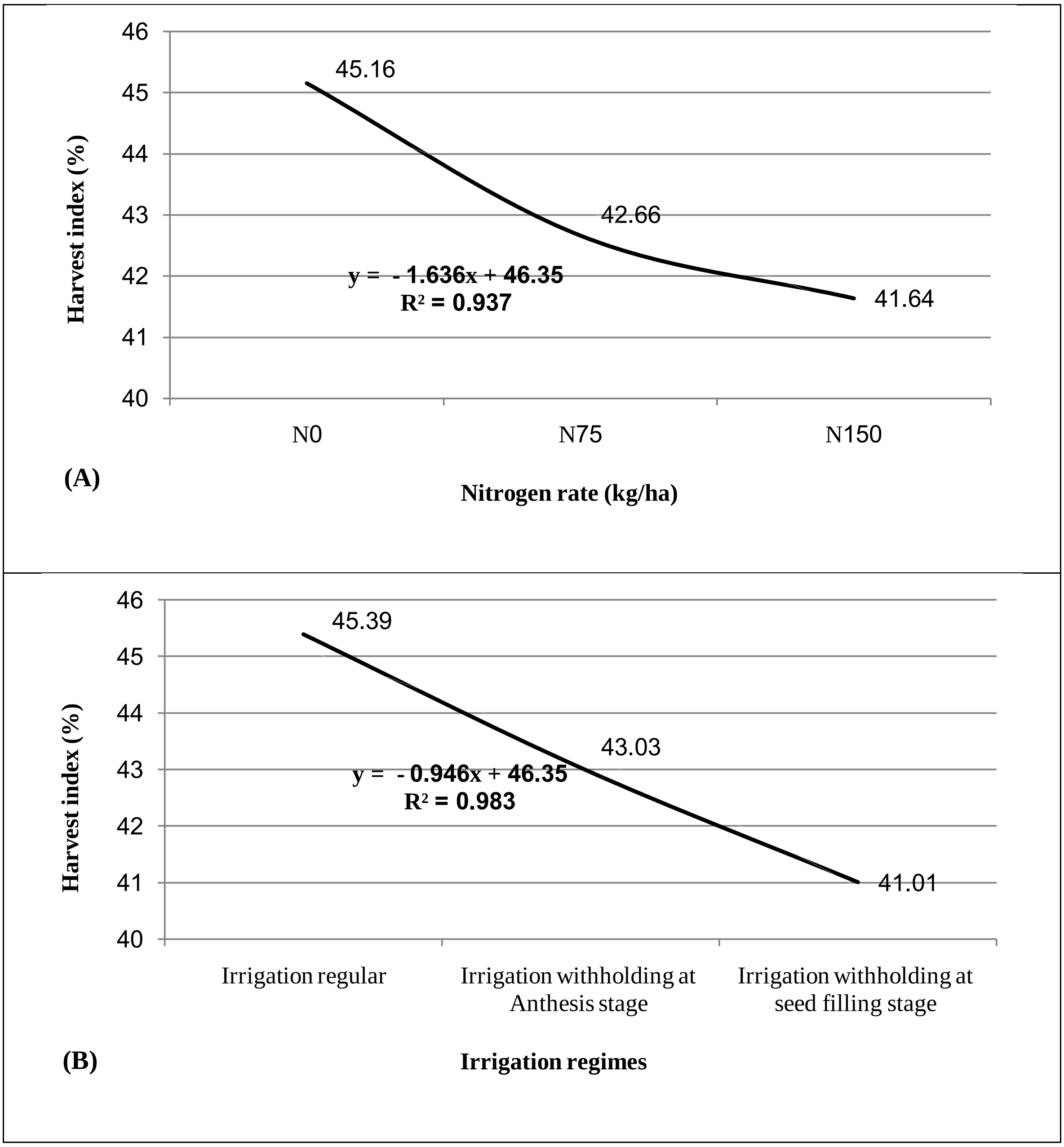

Figure 11: Response of harvest index to nitrogen application (A) and irrigation regimes (B)

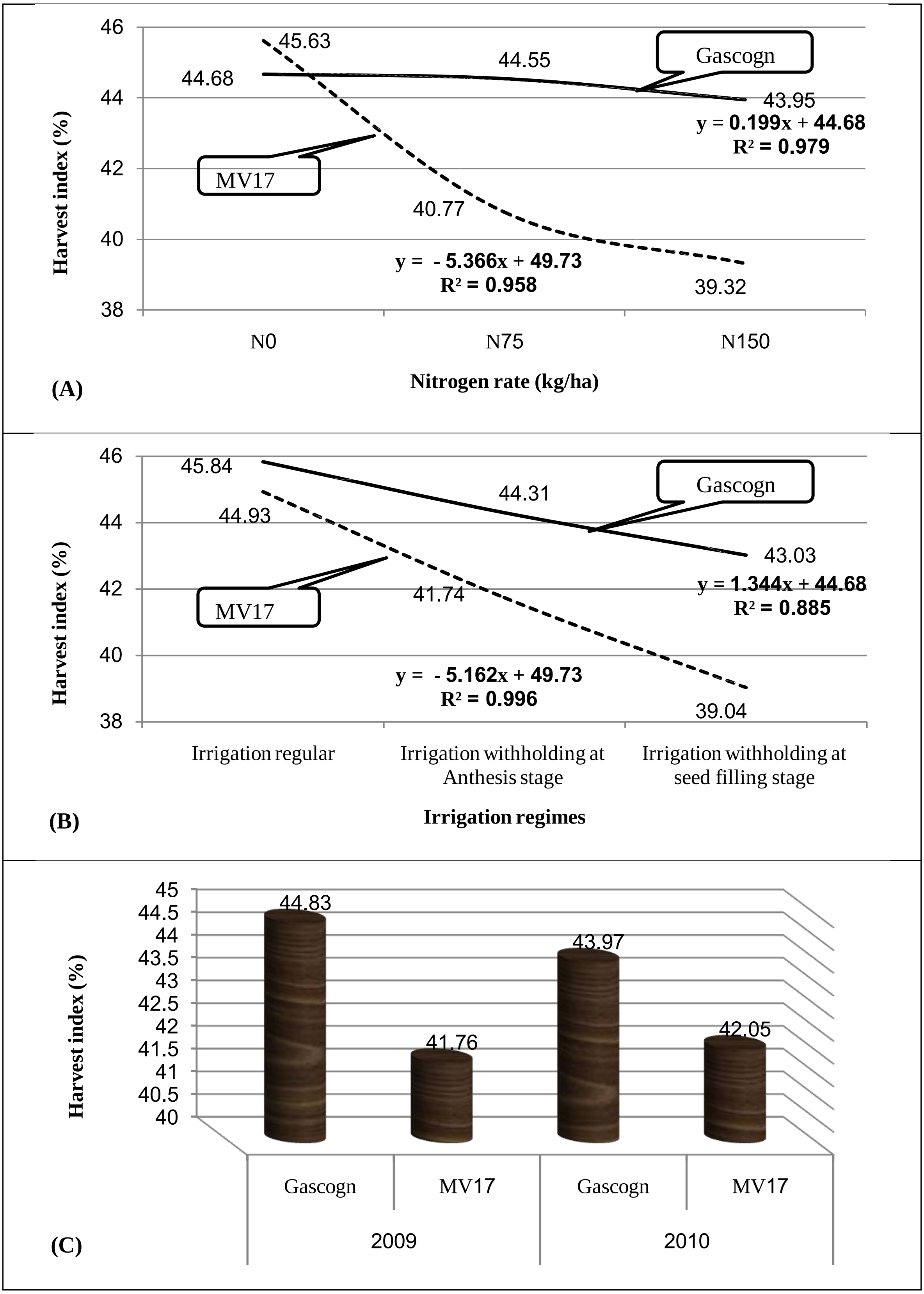

Figure 12: Changes in harvest index in wheat cultivars affected by nitrogen application (A), irrigation regimes (B) in both years (C)