



# Effect of irrigation and nitrogen application on water productivity and performance of Cotton (*Gossypium sp.*)

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## ABSTRACT

An experiment was conducted at research farm, Agricultural research sub-station, Hanumangarh, a unit of Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Kharif* season, 2016 to study the effect of water and nitrogen application rates on yield attributes, yield and water productivity of cotton (*Gossypium sp.*). Cotton variety Sri ram 6588 BG II was planted using 3 levels of irrigation (200, 400 and 600 mm) and 4 level of nitrogen (0, 75, 150 and 225 kg ha<sup>-1</sup>) in split plot design with three replications. The water and nitrogen application rates had significant influence on yield attribute, yield and water productivity of cotton. The results indicated that the irrigation level 400 mm recorded significantly higher number of bolls per plant (37.08), boll weight (3.83 g), seed cotton yield (2568 kg ha<sup>-1</sup>), lint yield (734 kg ha<sup>-1</sup>) and seed yield (1834 kg ha<sup>-1</sup>) but was at par with irrigation level 600 mm. The highest stalk yield (4947 kg ha<sup>-1</sup>), biological yield (7599 kg ha<sup>-1</sup>) and seed index (9.21) were observed with irrigation level 600 mm. However, highest water productivity (0.405 kg m<sup>-3</sup>) was observed with irrigation level 200 mm. The maximum number of bolls per plant (41.78), stalk yield (4745 kg ha<sup>-1</sup>), biological yield (7462 kg ha<sup>-1</sup>) and water productivity (0.392 kg m<sup>-3</sup>) were found with nitrogen application rate 150 kg ha<sup>-1</sup>. The highest boll weight (4.05), seed index (8.47), seed cotton yield (2813 kg ha<sup>-1</sup>), seed yield (803 kg ha<sup>-1</sup>) and lint yield (2010 kg ha<sup>-1</sup>) were observed with nitrogen level 225 kg ha<sup>-1</sup>. The irrigation and nitrogen level had no significant effect on plant population at harvest. Irrigation along with nitrogen levels significantly influenced the yield attributes, yields and water productivity of Bt cotton. The combined application of irrigation level 600 mm and N @ 225 kg ha<sup>-1</sup> resulted in significantly higher number of bolls per plant, seed cotton yield, stalk yield and total water productivity in comparison to irrigation @ 200 mm and N @ 0 kg ha<sup>-1</sup> (control).

**Key words:** Irrigation, Nitrogen, Yield, Water productivity, Cotton

## INTRODUCTION

Any kind of crop production activity mainly confined around the proper management of water and nutrients. It became more important in the hunger and thirsty area like North West Rajasthan, where annual rainfall ranges from 150-350 mm and available soil nitrogen ranges from 90-130 kg ha<sup>-1</sup> and hence, efficient management of these two factors of crop production can decide crop productivity. The irrigated North Western plain zone (Ib) of Rajasthan, comprising Sriganganagar and Hanumangarh districts, is part of arid tract of India. In this region, low rainfall or unequal distribution of rains during crop growing period affect the crop yield. Hence, irrigation is the utmost important factor for crop production in arid regions throughout the dry season (Dagdalen *et al.*, 2006). In many regions, the water resources and availability of fresh water are decreasing with depletion of water reservoirs and their use in other

sectors like urbanization and industrialization. According to Payero *et al.* (2006), this problem may be faced by farmers from many regions of the world. In this situation the optimization of crop yield and water productivity can be achieved through reducing the amount of irrigation water either by applying less water than required throughout the whole growing season or by avoiding irrigation at less sensitive water stress phases, allowing great economic return (Zegbe Domingues *et al.*, 2003). Nearly 62% of Indian soils particularly low in organic matter as in arid region, are deficient in nitrogen and adequate supply of nitrogen associated with vigorous vegetative growth leads to more efficient utilization of available inputs and finally to higher crop productivity. Cotton (*Gossypium sp.*) is a most important fibre and cash crop grown commercially for agricultural and industrial purposes (Smith, 1999). Although cotton is mainly grown for fibre

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purpose but it has many valuable uses as its seed contain 30% starch, 16.2% protein and 25% oil (Cobley and Steel, 1976).

Cotton production is mainly affected by water stress condition (Pettigrew, 2004; Dagdelen *et al.*, 2006; Basal *et al.*, 2009; Rao *et al.*, 2016). Insufficient supply of nitrogen and irrigation causes water and nitrogen stress during the sensitive growth stages, flowering and fruit-setting stages, which can lead to a reduced number of fruiting positions, boll shedding, and poorly developed bolls (Aujla *et al.*, 2005). Contrarily, over-irrigation in cotton can cause undesired more vegetative growth, which may cause reduction in cotton yields (Karam *et al.*, 2006). A properly managed irrigation improves the water productivity and nutrient uptake. Although the high costs to initial investments are a disadvantage, the profits can be quickly recovered with appropriated crop fertilization. So, fertilization should be done only with the quantities required by crop, avoiding deficits or waste. To reach this goal, high yields must be achieved in order to obtain the maximum economic yield of the crop (Zonta *et al.*, 2016). Keeping this in view, the present experiment entitled, "Effect of water and nitrogen application rates on yield attributes, yield and water productivity of cotton (*Gossypium sp.*)" was carried out during *kharif* season 2016.

## MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2016 at Agricultural Research Sub Station, Hanumangarh, SKRAU, Bikaner. The soil was silty clay with pH 7.6, having 0.19% organic carbon, 196.57 kg ha<sup>-1</sup> available N, 33.65 kg ha<sup>-1</sup> available P and 378.12 kg ha<sup>-1</sup> available K. The experiment was laid out in split plot design with three replications. The treatments comprised of 3 irrigation levels (200, 400 and 600 mm) and 4 nitrogen levels (0, 75, 150 and 225 kg ha<sup>-1</sup>). The cotton variety 'Sri Ram 6588 BG II' was sown manually in 90 cm × 67.5 cm row and plant spacing on 16 June 2016. The net plot size was 3.6 × 4.05 m. A uniform pre sowing irrigation of 60 mm was applied to all plots. The measured quantity of irrigation to each plot was applied via a 2 inch PVC pipe fitted with water flow meter (Kranti). The plots receiving 200, 400 and 600 mm irrigation were irrigated at 4 (30, 60, 90 and 120 DAS), 6 (30, 45, 60, 75, 90 and 120 DAS) and 8 (30, 45, 60, 75, 90, 105, 120 and 135 DAS) times, respectively. The rate of application of water was 50 mm each irrigation in case of I<sub>200</sub> treatment. In, I<sub>400</sub> treatments the first

irrigation was of 50 mm, and rest of 5 irrigations of 70 mm. In case of I<sub>600</sub> treatment, the first and second irrigation was of 50 and 70 mm, and rest of 6 irrigations of 80 mm. The nitrogen was applied in the form of urea as per sub plot treatment in three splits *viz.* 1/3 as basal at sowing, 1/3 at 30 DAS along with 1<sup>st</sup> irrigation and remaining 1/3 at the time of bud formation at the time of 5<sup>th</sup> irrigation (90 DAS). The phosphorus was applied @ 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> through SSP as per recommendation of cotton. Five random plants were selected from each plot, excluding the border row, for taking observations on yield attributes. The water productivity was computed by summing up water from irrigation and rainfall during the entire crop season. As there is no meteorological observatory established in Hanumangarh district, hence weekly weather data obtained from nearby district (recorded at meteorological observatory of IMD located at Sriganganagar). *Kharif* season 2016 experienced a total of 253.8 mm rainfall during the crop growing season.

## RESULTS AND DISCUSSION

### *Yield attributes and yields*

#### *Irrigation levels*

Irrigation levels significantly influenced the yield and yield attributes *viz.* number of bolls per plant, boll weight, seed index, harvest index as well as (seed cotton, lint, seed, stalk and biological) yield (Table 1 and 2). Except harvest index, all these parameters increased with increasing levels of irrigation from 200 to 600 mm. Irrigation level 400

**Table 1.** Effect of irrigation and nitrogen levels on yield attributes of cotton

Treatments	Plant stand at harvest ('000 ha <sup>-1</sup> )	No. of bolls per plant	Boll weight (g)	Seed index (g)
<i>Irrigation levels</i>				
I <sub>200</sub>	16.00	31.58	3.14	6.50
I <sub>400</sub>	16.07	37.08	3.45	8.42
I <sub>600</sub>	16.15	40.58	3.83	9.21
SEm±	19.44	1.39	0.10	0.18
CD (P=0.05)	NS	5.45	0.39	0.72
<i>Nitrogen levels</i>				
N <sub>0</sub>	16.10	24.67	2.81	7.49
N <sub>75</sub>	16.18	34.22	3.30	8.05
N <sub>150</sub>	16.21	41.78	3.73	8.17
N <sub>225</sub>	16.25	45.00	4.05	8.47
SEm±	41.43	1.56	0.07	0.09
CD (P=0.05)	NS	4.63	0.22	0.29

**Table 2.** Effect of irrigation and nitrogen levels on yields (kg ha<sup>-1</sup>) and harvest index (%) of cotton

Treatments	Seed cotton yield (kg ha <sup>-1</sup> )	Lint yield (kg ha <sup>-1</sup> )	Seed yield (kg ha <sup>-1</sup> )	Stalk yield (kg ha <sup>-1</sup> )	Biological yield (kg ha <sup>-1</sup> )	Harvest index (%)	Total water productivity (kg m <sup>-3</sup> )
<i>Irrigation levels</i>							
I <sub>200</sub>	2078	594	1485	3131	5210	40.25	0.405
I <sub>400</sub>	2568	734	1834	4213	6781	37.95	0.360
I <sub>600</sub>	2652	758	1894	4947	7599	35.91	0.290
SEm±	75	21	53	134	195	0.43	0.011
CD ( <i>P</i> =0.05)	293	84	209	527	767	1.70	0.044
<i>Nitrogen levels</i>							
N <sub>0</sub>	1961	560	1401	3087	5049	39.22	0.285
N <sub>75</sub>	2241	640	1601	3554	5796	38.76	0.328
N <sub>150</sub>	2716	776	1940	4745	7462	36.75	0.392
N <sub>225</sub>	2813	803	2010	5001	7815	37.41	0.400
SEm±	31	9	22	125	128	0.74	0.004
CD ( <i>P</i> =0.05)	93	26	66	372	379	NS	0.013

mm gave significantly highest number of bolls per plant which was at par with irrigation level 600 mm and it was 17.42 per cent higher than irrigation level 200 mm. However, the significantly highest boll weight and seed index were observed with irrigation level 600 mm. The better response may be due to more frequent and optimum supply of irrigation water, which not only increased nutrients availability in root zone but also better uptake of nutrients by the plant as well as better partition of these nutrients in actively growing plant parts. The improved growth evidenced by higher leaf area index and dry matter accumulation with an increased irrigation levels might be responsible for higher yield attributes of cotton at higher irrigation levels observed in this study.

Significantly higher seed cotton yield, lint yield and seed yield were recorded under irrigation at 400 mm, which was statistically at par with 600 mm and the seed cotton yield was 23.58 percent higher than irrigation level 200 mm. Irrigation level also increased the biological yield of *Bt* cotton. The increase in yield might be due to favourable moisture status in the root zone of the crop through irrigation which favoured better growth and development of plant. The stalk and biological yield increased with increasing level of irrigation and highest values for these parameters were recorded at 600 mm irrigation level. It was an account of its direct and positive influence on dry matter accumulation and number of bolls per plant as described in preceding paragraphs. The results are in conformity with the findings of Yadav and Chauhan (2013), Yadav and Chauhan (2016).

#### *Nitrogen levels*

Number of bolls per plant, boll weight, seed index (Table 1) and seed cotton yield (lint and seed yield), stalk yield, biological yield (Table 2) increased with increasing level of N application. The significantly highest boll weight, seed index, seed cotton yield, lint yield and seed yield were observed with N rate 225 kg ha<sup>-1</sup>. It was 44.13, 13.08, 43.45, 43.39 and 43.47 per cent higher than nitrogen level 0 kg ha<sup>-1</sup>. Further, significantly highest number of bolls per plant, stalk yield and biological yield were observed with 150 kg N ha<sup>-1</sup> (Table 2). It was 69.35, 53.70 and 47.79 per cent higher than nitrogen level 0 kg ha<sup>-1</sup>. The increase in all these parameters might be due to nitrogen fertilization because nitrogen is way of increasing Leaf area index and the plant enables to produce more branches leading to more number of bolls. The increase in the boll weight with increased N levels was attributed to increased seed and lint indices of seed cotton. Higher number of bolls with heavier weight under increased nitrogen fertilization together led to more seed cotton yield realization. Nitrogen led enhancement of leaf area culminating in more branches and thus more number of total bolls supports the present result. The present investigation results with respect to seed index in relation to nitrogen fertilization are in tune with the findings of Saleem *et al.* (2010). The enhanced *Bt* protein production at higher level of nitrogen fertilization might have led to greater and longer boll worm resistance and thus more boll retention. An increase in boll weight and yield with nitrogen fertilization also reported by Srinivasulu *et al.* (2006).

An increase in boll weight, number of branches with increase in nitrogen doses led to significant increase in biological yield. The results corroborate with the findings of Ali *et al.* (2011), Giri *et al.* (2014).

*Water productivity*

*Irrigation levels*

The water productivity progressively decreased with a gradual increase in irrigation levels. The application of 200 mm irrigation recorded highest water productivity closely followed by 400 mm and 600 mm irrigation levels (Table 2). The effect of irrigation levels on water productivity is in contrast to its effects on yield, as yield increased with an increase in irrigation levels. The relatively smaller increase in yield compared to amount of irrigation applied with an increase in irrigation levels is explanation of decrease in water productivity at higher irrigation levels observed in present study. The present study was indirectly supported by the findings of Yadav and Chauhan (2013).

*Nitrogen levels*

The water productivity increased with an increase in nitrogen levels, although the difference between 150 kg N ha<sup>-1</sup> and 225 kg N ha<sup>-1</sup> levels were not significant (Table 2). The improvement in water productivity with an increase in nitrogen fertilization observed in the present study might be attributed to increased leaf area which leads to reduction in evaporation component of evapo-

transpiration, smaller increase in evapo-transpiration compared to yield and better utilization of available soil water. The results are in agreement with the findings of Yadav and Chauhan (2016), who demonstrated that the addition of nitrogen in nitrogen deficient soil increased water productivity, when water is available.

*Combined effect of irrigation levels and nitrogen levels*

Irrigation along with nitrogen levels significantly influenced the number of bolls per plant, seed cotton yield, stalk yield and water productivity of Bt cotton. Irrigation at 600 mm and nitrogen rate @ 225 kg ha<sup>-1</sup> significantly improved these parameters in comparison to all the other parameters (Fig. 1, 2, 3 and 4). At the same level of nitrogen, increasing level of irrigation up to 600 mm significantly increased the number of bolls per plant, seed cotton yield, and stalk yield and water productivity. Similarly, at the same level of irrigation, increasing level of nitrogen up to 225 kg N ha<sup>-1</sup> significantly increased the number of bolls per plant, seed cotton yield, stalk yield and total water productivity of Bt cotton. The maximum number of bolls per plant, seed cotton yield, stalk yield and total water productivity was observed in I<sub>600</sub> N<sub>225</sub> treatment combination while minimum was observed in I<sub>200</sub> N<sub>0</sub> treatment combination. These results can be explained by the fact of under water deficit in which the N was not absorbed in the sufficient amount required for ideal growth. Thus, despite being applied, it was speculated that

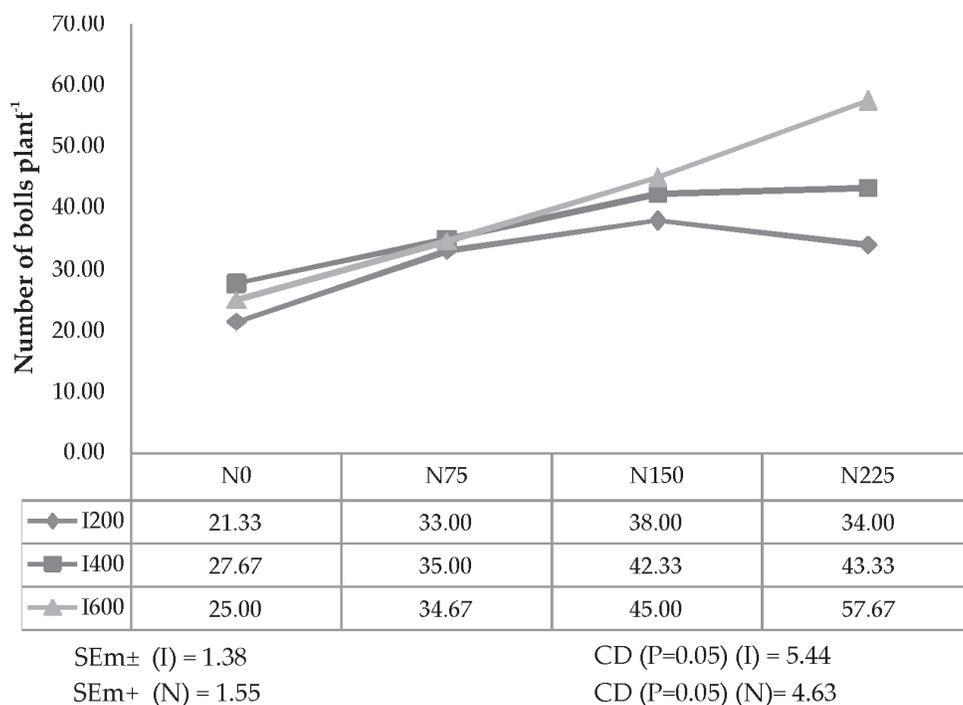


Fig. 1. Combined effect of irrigation and nitrogen levels on number of bolls plant<sup>-1</sup> of cotton

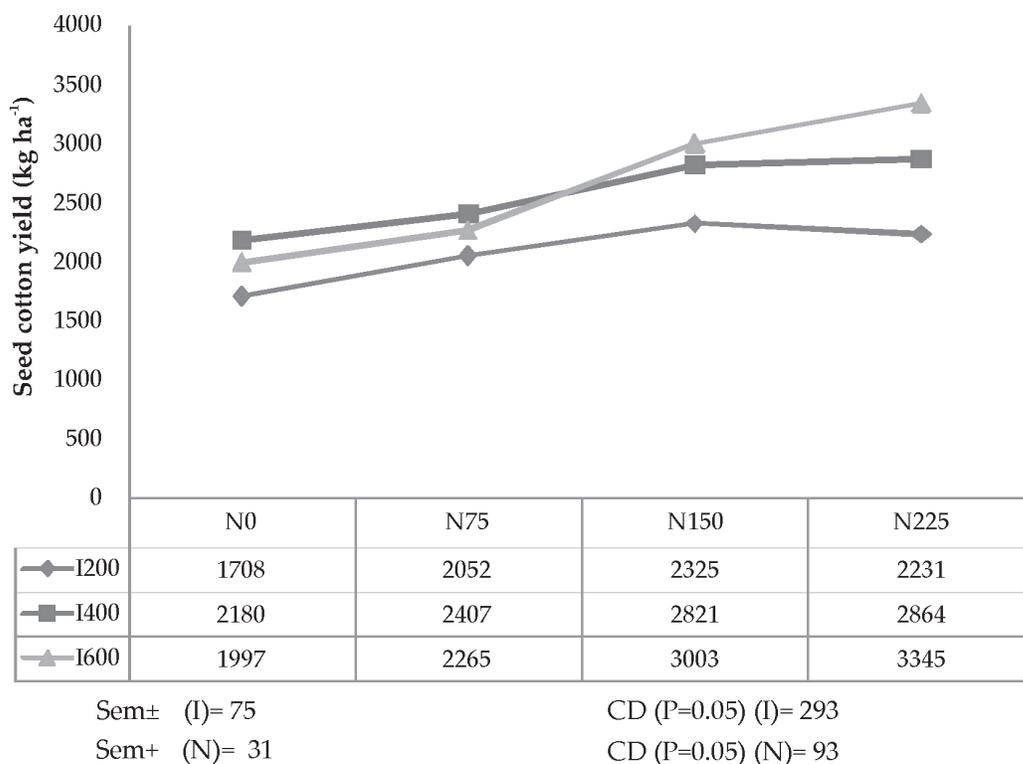


Fig. 2. Combined effect of irrigation and nitrogen levels on seed cotton yield (kg ha<sup>-1</sup>) of cotton

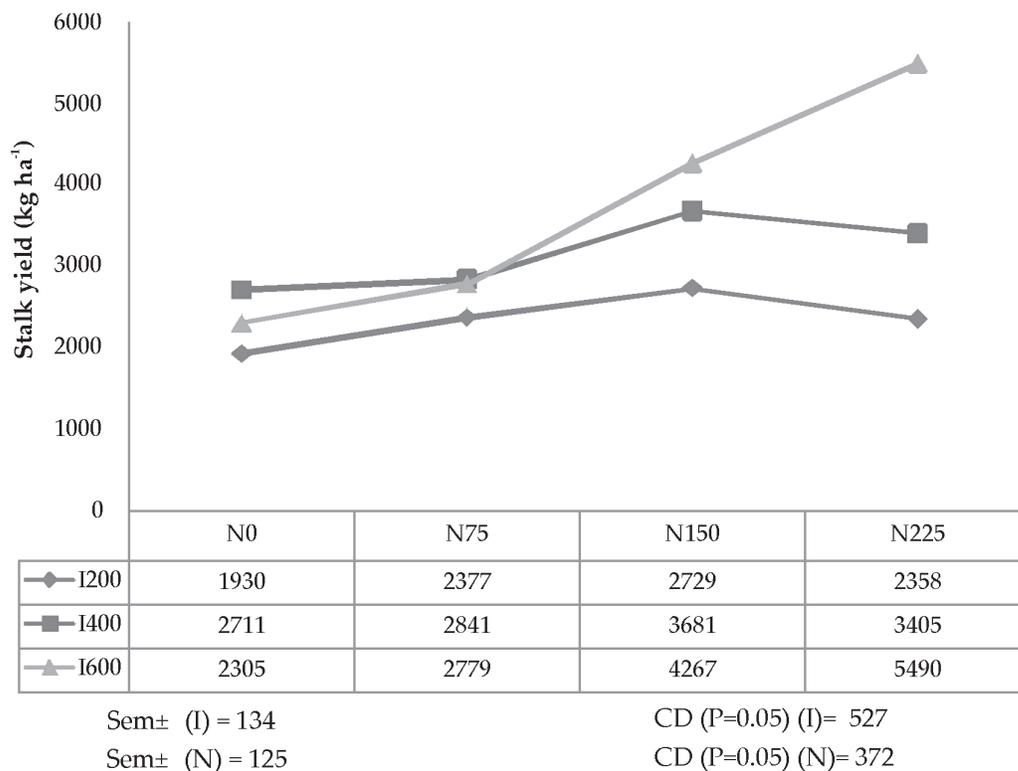


Fig. 3. Combined effect of irrigation and nitrogen levels on stalk yield (kg ha<sup>-1</sup>) of cotton

N was lost by volatilization. Further, because of silty clay soils, part of N was also supposedly lost by leaching. Aujla *et al.* (2005) remarked that lower N doses, applied in coverage, result in lower productivity regardless of the level of irrigation. The soil water content under ideal condition is important

to promote N uptake by plants. So, the correct water management is essential to avoid waste of inputs. Regarding the water treatments, cotton yield response was linear to the increase in irrigation levels for all N levels applied. The results of the present study also corroborate with those of Singh *et al.* (2010).

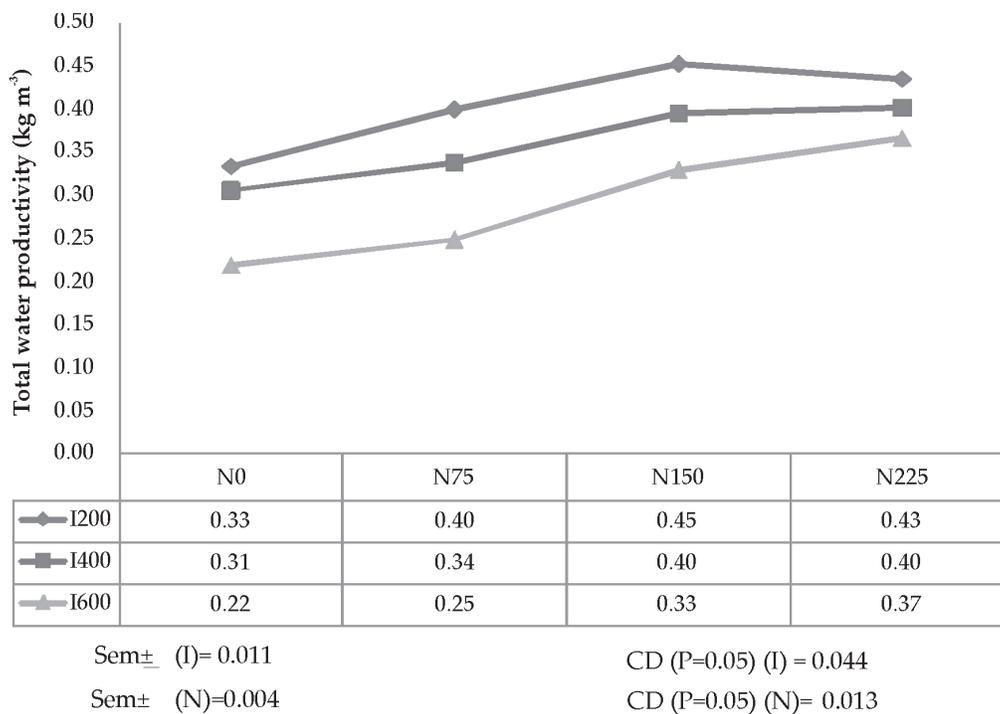


Fig. 4. Combined effect of irrigation and nitrogen levels on total water productivity ( $\text{kg m}^{-3}$ ) of cotton

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