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Effect of low-level irrigation and different-level of N-fertilizer on yield and yield components of corn hybrids (*Zea mays* L) in Kermanshah temperate climate, Western Iran

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ABSTRACT
To investigate the effect of different levels of N-fertilizer in diverse-content irrigation and drought-stress on yield and yield components of various hybrids of corn, an experiment has been conducted for two years (2016-2017) as split plot based on a randomized complete block design with four replications at Natural Resource and Agricultural Research Station, Kermanshah Province, Western Iran located in West Eslamabad (63 km west of Kermanshah). The amount of water-requirement has been assigned as main plots in three levels including 100%, 80% and 60% of water-requirement as perfect, moderate- and extreme-stress levels, respectively. Different levels of N-fertilizer (in the form of urea) were determined based on results of soil-experiment consisting of suggested-amount equal to 170 Kg N ha^{-1}, 30% higher than the suggested-amount (221 Kg N ha^{-1}), 30% lower than the suggested-amount (119 Kg N ha^{-1}), as well as corn hybrids (ksc260, ksc500, ksc703) were dedicated as subplots. In normal states, increasing N-fertilizer level of 119 Kg N ha^{-1} to 221 Kg N ha^{-1} improved these attributes, however, imposing drought-stress declined. While in stress-drought accompanied with increasing N-fertilizer from 119 Kg N ha^{-1} to 170 Kg N ha^{-1} improved these attributes. Meanwhile, the N-fertilizer effect has not been so important. The grain yield of ksc730 hybrid was higher than the others in the normal and moderate-stress, while reaction to N-fertilizer by ksc260 hybrid was better and led to more enhanced yield in the extreme drought-stress particularly accompanied via applying 221 Kg N ha^{-1}.

Keywords: *Zea mays* L, grain yield, yield components, drought stress, N-fertilizer level.
Article type: Research Article.

INTRODUCTION
Corn is known to be one of the most important food products in Iran. According to Iranian Ministry of Agriculture, given its importance in feeding livestock and poultry, corn is in the group of strategic products. However, it is also one of the major food imports into the country. As a main food in animal feeding and industry around the world, corn is of great importance that provides food security, especially in developing countries. According to some authors, one of the greatest agricultural achievements of human is the cultivation and development of corn worldwide (O'Leary 2016; Sahi *et al.* 2022). The area under cultivation, production and exploitation of corn has increased several times in the last five decades, and corn accounts for the fastest annual growth in Asia (about 4%) compared to other cereals (Hearn 2014). Although according to the estimates made by Food and Agriculture Organization (FAO) and the International Maize and Wheat Improvement Centre (CIMMYT), it was predicted that global corn production would have reached over 830 million tons by 2020, in practice, due to the recent financial crisis of industrialized countries and the global rise of energy carrier prices, corn demand and production (whose products can be used as biofuels or biodiesel), corn production has reached far beyond the estimates. Corn

is one of the basic products in meeting the food and fodder requirements of Iran. In terms of area under cultivation, this plant accounts for the third place among crops after wheat and rice and the first place in terms of production. In Kermanshah Province, Western Iran corn is one of the most important crops, with an average area under cultivation of over 45,000 hectares in the last 10 years. Kermanshah, after Fars and Khuzestan provinces, is ranked the second in terms of area under cultivation. Moreover, by 9 tons per hectare, it is ranked first in the country. However, in 2014, the area under corn cultivation in this province decreased by 30,000 hectares, reaching 15,580 hectares, the main reason was the lack of water in the region. Drought as the most important factor controlling crop yield affects all plant growth processes (Sedicio *et al.* 1999). Drought is one of the most important factors limiting corn production in the world, reducing the global corn yield by an average of 17% each year. In some areas, this reduction has been reported up to 70% (Dastannejad *et al.* 2010). Drought is the most important natural factor affecting the growth and production of crops in semi-arid regions of the world. On the other hand, nitrogen fertilizer is the main fertilizer required for corn (Shafiee & Safari 2011). According to CIMMYT investigators, lack of irrigation and nitrogen are the main factors reducing corn yield in the world (Casago 2006). By an average rainfall of 240 mm per year, Iran is classified as one of the arid to semi-arid regions. Drought is one of the major risks for successful crop production in Iran and other less developed countries (Golbashi *et al.* 2011; Sobhani & Safarianzengir 2020; Batayneh *et al.* 2022; Attafi *et al.* 2022). Among inanimate stresses, drought is known to be the most important limiting factor in corn production. Drought stress has many negative effects on corn growth in many parts of the world. Global warming and climate change can worsen the conditions in many agricultural areas (Jabbsing & Babu 2014). Water shortage can significantly reduce the growth, grain yield, yield components, and root system of maize genotypes. In semi-humid and low-humidity areas, unpredictable periods of drought cause significant reductions in corn yield (Kamara *et al.* 2002). On the other hand, nitrogen is the fourth major constituent of the plant dry weight and many important molecules such as proteins, nucleic acids, some hormones, chlorophyll and many of the major constituents of plants (Hopkins 2004). Nitrogen is the most important macro-element for plants' growth. It is also a key factor in achieving optimal yield in cereals (Rostami *et al.* 2008). Nitrogen is one of the most important nutrients limiting the yield of corn in different parts of the world. In fact, nitrogen fertilizer is essential to achieve maximum production in corn. The amount of nitrogen required depends on yield, inorganic nitrogen in the soil, soil type and environmental factors (Al-Bakir 2003; Ashouri 2019; Rakhimova *et al.* 2021). There has been a lot of studies on using nitrogen fertilizer in corn, most has been conducted in the full irrigation conditions. The effect of this fertilizer in different irrigation conditions has not yet been investigated, and very few studies have been performed on the interaction of nitrogen fertilizer and irrigation (Moser 2004). Drought stress is one of the important factors limiting crop yield, the extent of which depends on the nitrogen content of the plant (Arfat *et al.* 1996; Al-Dulaimy *et al.* 2022). Since nutrients enter the plant as water-soluble or move from cell to cell and from tissue to tissue in the plant, it is essential to investigate the interaction of these two stresses (Alizadeh Oghyanous *et al*. 2009).

MATERIALS AND METHODS

This study was carried out for two years from 2016 through 2017 at the Natural Resource and Agricultural Research Station, Kermanshah Province, Western Iran located in west Eslamabad (63 km west of Kermanshah). This station is located at the longitude of 47 degrees and 26 minutes east, the latitude of 34 degrees and 8 minutes north, and its altitude is 1346 meters above sea level. In terms of climate, it is located in a temperate region. This experiment was conducted as split plots (split factorial plot) in a randomized complete block design with four replications. In this study, the amount of water in three levels of (i) complete plant water requirement; (ii) 80% (mild drought stress); and (iii) 60% (severe drought stress) as the main factor followed by different levels of nitrogen fertilizer (urea) determined based on the soil test including: (i) the recommended amount based on soil test (170 kg / hectare of pure nitrogen equivalent to 369.5 kg of urea per hectare); (ii) 30% higher than this amount (221 kg of pure nitrogen equivalent to 480.3 kg of urea per hectare); and (iii) 30% lower than this amount (119 kg of pure nitrogen equivalent to 258.7 kg of urea per hectare); along with corn hybrids were placed in sub-plots. Nitrogen fertilizer was applied in three phases (based on the values considered in the fertilizer treatments: one-third was applied at the planting time and the rest was evenly applied as topdressing in two phases, i.e., seven-leaf phase and pre-flowering phase. In addition, three single cross hybrids, i.e., KSC703, KSC500 and KSC260 were investigated. All three hybrids belong to dent corn (*Zea mays* var. *indentata*) and were introduced by the Iranian Seed and Plant Research Improvement Institute, and their seeds are produced in Iran. KSC703 is in the late mature group and was introduced as a replacement for the 704 hybrid since 2011. Its growth period is about 135 days.

KSC500 is in the intermediate mature group and its growth period is about 120 days. KSC260, being one of the new hybrids of Iran, is known as Fajr. It is in the early mature group, and its growth period is about 110 days. Each plot was 7 m in length and 3 m in width, consisting of four planting lines. A row was planted as the margin between the sub-plots to prevent the infiltration of adjacent treatments. In order to control the amount of water and prevent the infiltration of water and fertilizer to the adjacent plots, irrigation control was conducted using a hydrofix system and a counter. For precise water control, each plot had four pipes with separate control valves. Prior to the five-leaf stage, the optimal irrigation for all plots was performed using sprinklers, so that the plant would be established. In the five-leaf stage, a hydrofix system and water counters were installed. Irrigation was applied based on water requirement and the amount of each treatment. From this phase on, measurements were made. The water requirement of the plant was calculated based on FAO Penman-Monteith equation and FAO Guideline No. 56 in 10-day periods and based on the meteorological statistics of the region.

Grain yield

In order to determine the yield, the ears of the middle 2 rows of each experimental plot were harvested and weighed manually when they are physiologically mature, after removing two-side lines and two plants from the beginning and end of each plot. Afterward, the seeds were separated from cob and the weight of seeds and cob were determined separately, thereafter, the grain yield per hectare was calculated in kilograms. The grain moisture content of each plot was determined and recorded separately by a hygrometer. Finally, the grain weight was calculated based on moisture content of 14% by ton per hectare.

Cob percentage

As many as 6 selected ears were weighed from each plot and after separating the seeds from the ears, the ears were weighed again and the percentage of ears was calculated using the following formula:

Ear cob percentage = ear cob weight ⁄ ear total weight × 100

Length of the ear

To measure ear length, 6 ears were randomly selected from each experimental plot. Then the average length of six ears (from the beginning to the end of the ear) of each experimental plot was measured and recorded by a ruler.

100-seed weighing

For this purpose, as many as 100 seeds were counted after being separated from the cobs by a seed counter, then were placed in an envelope and labelled. After being weighed with a sensitive scale, as their humidity content was already measured by a hygrometer, the weight was calculated based on a 14% humidity.

After two years of experiments, the results were collected and a two-year composite analysis was conducted based on the split factorial plot model. Statistical calculations including analysis of variance, mean comparisons with *Duncan's Multiple* Range Test were conducted by MSTAT-C and SAS. The correlation of the investigated features was conducted using SPSS, and graphs were drawn by Excel.

RESULTS AND DISCUSSION

Grain yield

The mutual effects of irrigation treatments and nitrogen levels on grain yield were significant at a 1% level (Tables 1-4). The highest grain yield was 13.9 tons per hectare (average of hybrids and irrigation levels), obtained in the optimal irrigation treatment and the highest amount of fertilizer application (W_1N_3). The lowest grain yield (6.4 ton ha^{-1}) was related to the treatment of severe drought stress and the lowest amount of fertilizer (W_3N_1). In optimal irrigation conditions, increasing nitrogen fertilizer application increased grain yield, however, in mild and severe moisture stress conditions, nitrogen application increased the yield to the recommended level (170 kg ha^{-1}), albeit by further increase in nitrogen fertilizer (221 kg ha^{-1}), no increase was observed in grain yield (Fig. 1). Khazaei *et al.* (2005) also stated that high percentage of leaf nitrogen under stress conditions can upraise grain yield to some extent, however, the yield either remained constant or decreased. Excessive increase in leaf chlorophyll does not seem to be effective in these conditions and yield may be reduced by other limiting factors. It can be stated that the simultaneous increase in soil moisture and nitrogen lead to the upraised grain yield.

However, in the case of moisture stress, the elevated nitrogen may reduce grain yield. Moreover, Mojadam *et al.* (2012) have reported that in the mild drought stress conditions, elevating in nitrogen, just like the optimal irrigation conditions, can significantly upraises the grain yield. In their experiment, by applying 180 and 220 kg pure nitrogen per hectare in optimal irrigation conditions and mild drought stress, grain yield increased significantly compared to 140 kg pure nitrogen. However, low grain yields were achieved at all levels of nitrogen under severe drought stress conditions. Moreover, increased nitrogen application under severe drought stress had no significant effect on upraising in the grain yield, while it increased imperceptibly at high nitrogen levels Mojadam *et al.* (2012). There was a significant difference between the hybrids, and the reaction of the hybrids was different in different water conditions. Ksc703 (belonging to the group late mature corn) had the highest yield under normal conditions, and by increasing in the amount of nitrogen fertilizer from 119 to 221 kg ha^{-1}, its yield increased from 12.9 ton ha^{-1} to 15.4 ton ha^{-1}. However, in mild stress conditions, by elevation in the amount of nitrogen fertilizer from 119 to 170 kg ha^{-1}, the yield upraised from 11.25 to 12.58 tons ha^{-1}. Albeit, as nitrogen fertilizer was elevated to 221 kg ha^{-1}, the grain yield reached 10.5 ton ha^{-1}. In comparison, by 170 kg nitrogen fertilizer, the yield declined. A similar reaction was found under severe drought stress conditions elevating up to 170 kg ha^{-1}, however, declined to 221 kg as nitrogen fertilizer upraised. The Ksc500 hybrid (in the intermediate mature group) reacted differently to nitrogen fertilizer under different water conditions. Like Ksc703, under full irrigation conditions, as nitrogen fertilizer increased from 119 to 221 kg ha^{-1}, its yield upraised from 10.43 to 13.1 ton ha^{-1}. Under mild stress conditions, its yield upraised from 9.5 to 11.1 ton ha^{-1} by elevating the fertilizer from 119 to 221 kg ha^{-1}. The more nitrogen fertilizer, the higher the yield. However, under severe drought stress conditions, by increasing nitrogen fertilizer from 119 to 170 kg, the yield upraised from 6 to 7 ton ha^{-1}. Albeit, when it reached 221 kg, the grain yield was 6.8 ton ha^{-1}, which is not significantly different from 7 tons. The best amount of fertilizer for Ksc500 in normal conditions and mild drought stress was 221 kg ha^{-1}. However, in severe drought stress, 170 kg ha^{-1} nitrogen fertilizer resulted in the best yield. Ksc260 (belonging to the early mature group) exhibited a same reaction as Ksc500. Under normal conditions and mild drought stress, the best amount was 221 kg ha^{-1}, while in severe drought, 170 kg ha^{-1} displayed the best results.

Table 1. The effect of irrigation and nitrogen fertilizer levels on the grain yield of maize hybrids.

Irrigation levels	Nitrogen fertilizer level	Ksc703	Ksc500	Ksc260
Full irrigation	Recommended level -30%	12.89	10.43	10.66
	Recommended level	14.86	11.92	12.30
	Recommended level +30%	15.40	13.10	13.31
80% of water requirement	Recommended level -30%	11.25	9.52	9.7
	Recommended level	12.58	10.64	11.2
	Recommended level +30%	10.48	10.7	11.1
60% of water requirement	Recommended level -30%	6.80	6.00	6.12
	Recommended level	6.70	6.40	6.72
	Recommended level +30%	6.67	6.45	6.8

Cob rate (%)

By increasing the severity of water stress, cob rate (%) elevated significantly (Tables 4-7). The lowest rate, i.e., 13.9%, was related to providing the complete water requirement for the plant, while the highest, i.e., 15.9%, to severe moisture stress (Fig. 4). In other words, under stress conditions, the ratio of wood to grain per ear upraised compared to the optimal conditions. The elevated cob wood rate (%) is a negative trait in corn cultivation. Under drought stress, the number and weight of grains, being the main reservoirs for receiving photosynthetic materials, declined. Thus, a larger portion of photosynthetic materials accumulated in the ear is allocated to cob. The high cob rate (%) is not a desirable trait in the elevated grain yield, since among the total photosynthetic materials allocated to cob, some is stored in cob and the rest in the seeds. Thus, the higher the capacity of the seeds to accept photosynthetic products, the less the amount of material accumulated in the cob; thus the yield will be elevated.

Different levels of nitrogen fertilizer had a significant effect on the percentage of cob. The highest rate of cob (15%) was observed once application of 119 kg ha^{-1} pure nitrogen, while the lowest (14.5%) by 221 kg ha^{-1}. The cob rate was 14.6%, when 170 kg ha^{-1} N was applied. It was not significantly different from the treatment of 221 kg ha^{-1}. It can be stated that the elevated nitrogen fertilizer upraises the share of seeds from photosynthetic materials in comparison with the cob and as a result, the cob rate declines. In addition, the mutual effect of irrigation and nitrogen fertilizer on the cob rate (%) was not significant.

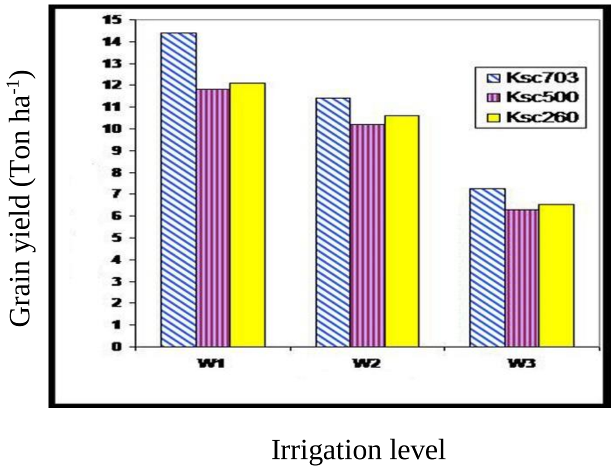


Fig. 1. Effect of irrigation levels on the grain yield in the different maize hybrids (Ksc 500, Ksc 703 and Ksc 260).

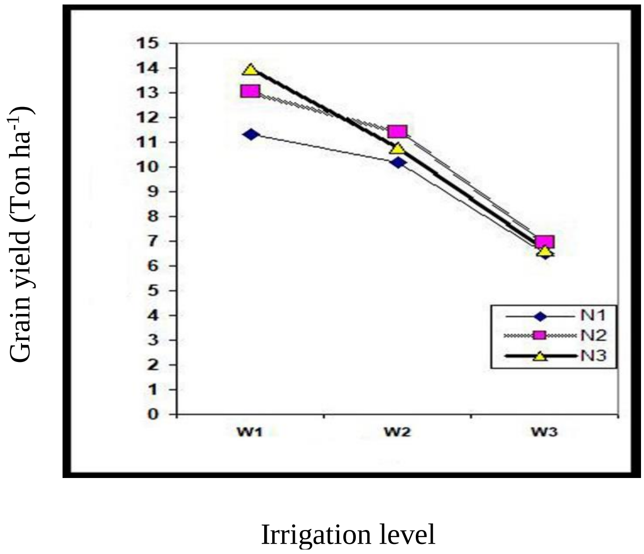
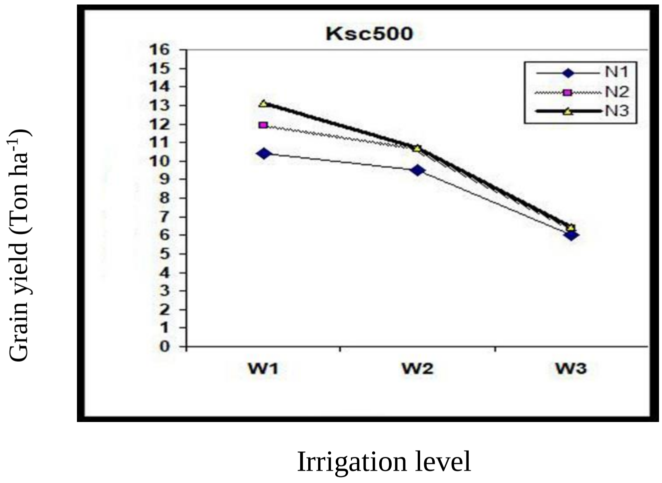
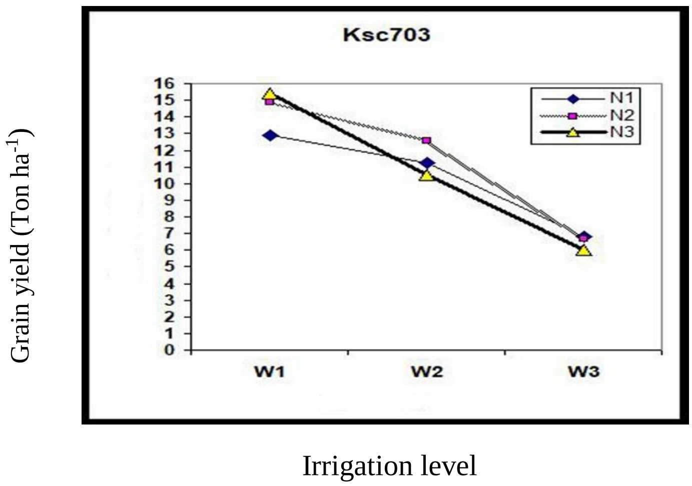


Fig. 2. Effect of irrigation levels on grain yield in the different maize hybrids (Ksc 500, Ksc 703 and Ksc 260); Nitrogen fertilizer: $N_1 = 119$, $N_2 = 170$ and $N_3 = 221$ kg ha^{-1}.

Table 2. Effect of irrigation level and nitrogen fertilizer levels on cob percentage in maize hybrids.

Irrigation levels	Nitrogen fertilizer level	Ksc703	Ksc500	Ksc260
Full irrigation	Recommended level -30%	14.6	14.9	13.4
	Recommended level	14.2	14.5	12.7
	Recommended level +30%	14.2	14.4	12.8
80% of water requirement	Recommended level -30%	14.8	15.2	13.6
	Recommended level	14.4	15.3	13
	Recommended level +30%	14.2	14.8	13.1
60% of water requirement	Recommended level -30%	16.1	17.9	14.8
	Recommended level	16.1	17.5	13.9
	Recommended level +30%	15.8	17.6	13.7





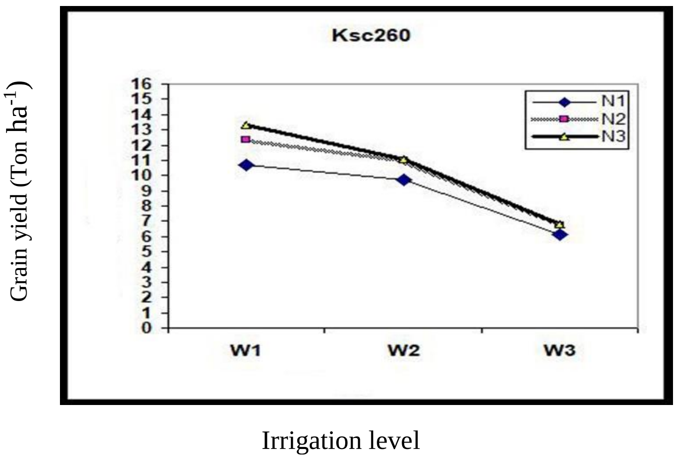


Fig. 3. Effects of irrigation and nitrogen (N) fertilizer levels on the 100-grain weight in different maize hybrids (Ksc 500, Ksc 703 and Ksc 260); N_1 = 119, N_2 = 170 and N_3 = 221 kg ha^{-1}.

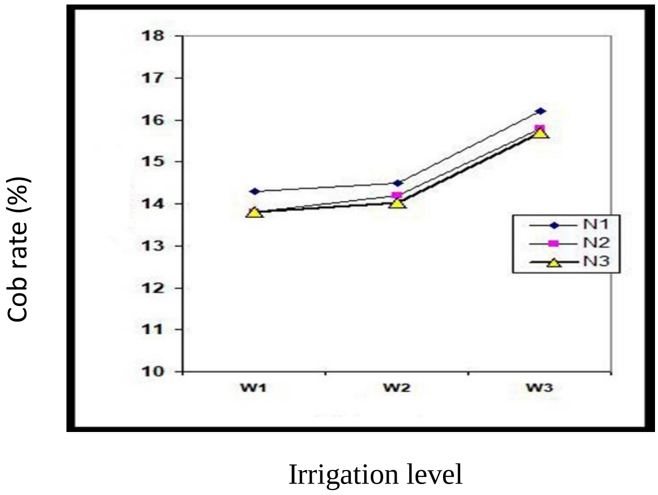


Fig. 4. Effect of irrigation levels on cob rate (%) in the different maize hybrids (Ksc 500, Ksc 703 and Ksc 260).

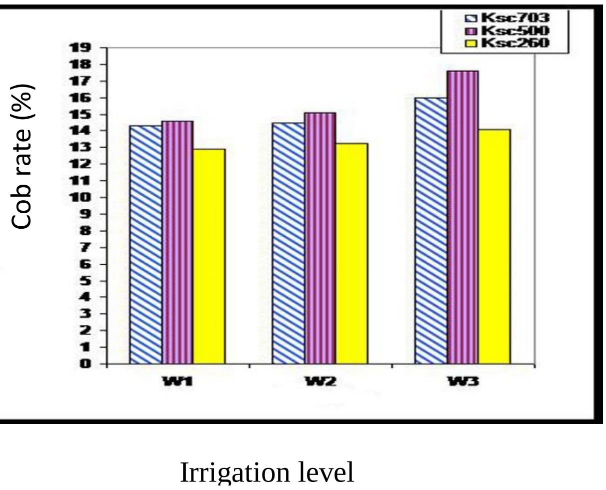


Fig. 5. Effect of irrigation levels and nitrogen (N) fertilizer levels on cob rate (%) in the different corn hybrids (Ksc 500, Ksc 703 and Ksc 260); N_1 = 119, N_2 = 170 and N_3 = 221 kg ha^{-1}.

100-seed weight

The results showed that the mutual effect of drought stress and nitrogen on 100-grain weight was significant (Table 4). By comparing the means using Duncan's test, it was found that the weight of 100 seeds is affected by different treatment combinations in different statistical classes. The maximum weight of 100 seeds (272.8 g) belonged to the optimal irrigation treatment and the highest level of nitrogen (W_1N_3). The minimum weight of 100 seeds (224.7 g) was observed in the treatment of severe drought stress and the lowest amount of fertilizer (W_3N_1). Under optimal irrigation, elevating nitrogen fertilizer upraised 100-seed weight. However, under drought stress treatments (mild and severe), the elevated nitrogen fertilizer up to 170 kg, upraised the 100-seed weight, while further elevation of nitrogen fertilizer in these treatments led to a declined the weight (Fig. 6). There was a significant difference between the hybrids. Under normal and stress conditions, Ksc703 exhibited the highest 100-seed weight, while the Ksc260 and Ksc500 hybrids were placed in the second and third order, respectively. Ksc260 reacted the best to nitrogen fertilizer under severe stress conditions (Table 4).

Table 3. Effect of irrigation rate and nitrogen fertilizer levels on 100-seed weight in maize hybrids.

Irrigation levels	Nitrogen fertilizer level	Ksc703	Ksc500	Ksc260
Full irrigation	Recommended level -30%	276.3	234.8	255.8
	Recommended level	289.3	249.1	266.1
	Recommended level +30%	299.7	256.3	269.1
80% of water requirement	Recommended level -30%	263.2	221.7	236.1
	Recommended level	266.9	227.3	243.3
	Recommended level +30%	264.2	231.4	236.4
60% of water requirement	Recommended level -30%	241.5	214.9	227.7
	Recommended level	253.6	215.7	236.4
	Recommended level +30%	251.1	214.8	228.1

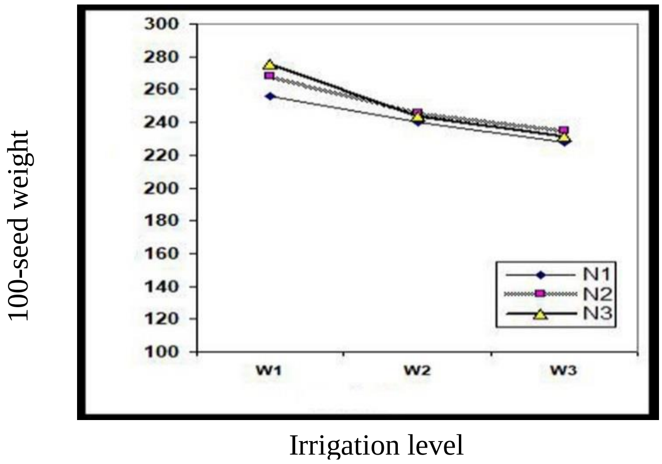


Fig. 6. Effects of irrigation level and nitrogen (N) fertilizer levels on the 100-seed weight (g) in the different corn hybrids (Ksc 500, Ksc 703 and Ksc 260); N_1 = 119, N_2 = 170 and N_3 = 221 kg ha^{-1}.

Length of the ear

Based on the results, the maximum ear length (16.8 cm) was obtained by applying 221 kg ha^{-1} pure nitrogen under optimal irrigation conditions. Under mild moisture, ear length elevated by the upraised nitrogen fertilizer. However, under severe stress, elevating in the amount of fertilizer to 170 kg ha^{-1}increased ear length. Albeit, elevating in the fertilizer to 221 kg ha^{-1}, did not exhibit significant difference from 170 kg ha^{-1}, since in severe drought stress, plant's nitrate uptake from the soil is limited. Ksc703 by an average of 16.4 cm displayed the highest ear length, while Ksc500 by 13.1 cm exhibited the lowest. Ksc703 revealed the highest ear length under normal and stress conditions, while Ksc260 was placed in the second order. In another experiment in Sistan Province, Iran, drought stress severely declined the ear length in Ksc703 (Ashofteh Bigharari *et al*. 2011). Moreover, in all three hybrids and under drought stress conditions, the ear length increased by the elevated amount of nitrogen fertilizer.

Table 4. Effect of irrigation level and nitrogen fertilizer levels on ear length (cm) in maize hybrids.

Irrigation levels	Nitrogen fertilizer level	Ksc703	Ksc500	Ksc260
Full irrigation	Recommended level -30%	17.05	13.3	15.2
	Recommended level	17.7	14	15.5
	Recommended level +30%	17.8	14.2	16.1
80% of water requirement	Recommended level -30%	16.9	12.7	14.1
	Recommended level	17	13.5	14.4
	Recommended level +30%	16.6	13.6	15.3
60% of water requirement	Recommended level -30%	14.6	11.4	11.9
	Recommended level	14.7	12.7	13.4
	Recommended level +30%	15	12.2	13.1

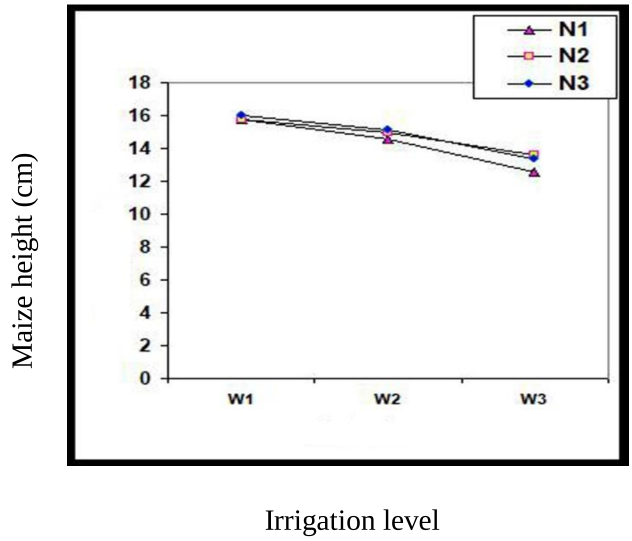


Fig. 7. Effects of irrigation level and nitrogen (N) fertilizer levels on the plant height in the different maize hybrids (Ksc 500, Ksc 703 and Ksc 260); N_1 = 119, N_2 = 170 and N_3 = 221 kg ha^{-1}.

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