Invinsa Application to Reduce Water Stress Effects on Corn Growth and Yield at Maricopa, AZ, 2012

M. J. Ottman and B. A. Kimball

Abstract

Invinsa blocks ethylene perception by plants and can reduce the negative effects of water stress on crop growth. The objective of this study is to measure the effect on corn growth and yield of Invinsa application at incipient water stress. A study was conducted at the University of Arizona Maricopa Agricultural Center where Invinsa was applied on 15 May in blocks with adequate or deficit irrigation. The deficit irrigation block received no irrigation water for 7 days past incipient stress beginning on 15 May, but otherwise received adequate water during the other parts of the season. Invinsa had little or no effect on crop growth measured at five different dates during the growing season. Invinsa had no effect on grain yield, grain moisture content, harvest index, ear number, kernels per ear, kernel weight, and silking date. We were not able to measure an effect of Invinsa on photosynthetic rate, conductance to water, intercellular CO_2 concentration, vapor pressure deficit, or leaf temperature. However, Invinsa increased daily water use at various time periods, particularly in the adequate irrigation regime. The lack of a response this year to Invinsa, other than water use, is similar to the results from last year where no consistent response was measured. Invinsa has increased corn yield in other regions, and heat and/or water stress at the Maricopa may mask the effects of Invinsa or render it ineffective.

Introduction

Invinsa (1-methycyclopropene, 1-MCP) is similar in structure to ethylene and interacts with the ethylene receptors in plants. An increase in ethylene is a stress signal to the plant. Blocking ethylene perception by application of Invinsa prevents the plant from sensing stress and could reduce the negative effects of stress on plant growth. The produce industry has used Invinsa since 1997 to maintain the quality of harvested fruits and vegetables during transportation, storage, and retail display.

Recent work has shown that Invinsa may have a use not only post-harvest on fruits and vegetables, but also during the growth of crops. Preliminary trials have shown that application of Invinsa at incipient water stress between the 10^{th} leaf and milk stage in corn results in a 10 bu/acre yield gain (5-10%) by mitigating a decline in photosynthesis. A negative effect can be observed about 10% of the time for applications at tasseling. Direct effects can be observed for 10-14 days, but morphological effects may be observed for up to 30-40 days after application. Best results have been obtained where corn yielded between 120 and 180 bu/acre.

The highest yield increases have been obtained when Invinsa has been applied at "incipient" stress. Soil water measurements using tensiometers combined with weather forecasts have not been effective in predicting plant response. Visible stress combined with weather forecasts is a slightly better in predicting plant response to Invinsa. However, photosynthesis can decrease before water stress is visible to the eye, so visible stress provides a signal that is too late. The "Decision Support System for Agrotechnology Transfer (DSSAT) Drought Stress Pattern" may provide an indication of incipient water stress, but this tool requires the water holding capacity of the soil to be provided. A promising tool to determine incipient water stress is the infrared thermometer to measure canopy

temperature. As plants become stressed for water, the stomates begin to close and leaf temperature rises before stress can be observed visibly.

The objective of this study is to measure the corn yield response to Invinsa application at incipient stress measured with infrared thermometry. This is the second year that this study has been conducted.

Methodology

A field test of the effect of Invinsa on corn growth and yield was conducted at the University of Arizona Maricopa Agricultural Center. The field was previously cropped to barley. For weed control, Stealth was applied preplant. Nitrogen fertilizer was be applied preplant at a rate of 48 lbs N/acre as urea (46-0-0), side-dressed at a rate of 50 lbs N/acre as UAN 32 (32-0-0) on 9 April, and applied in the irrigation water in three applications as UAN32 (32-0-0) on 23 April, 3 May, and 8 May at rates of 57, 40, and 17 lbs N/acre, respectively, for a total seasonal nitrogen rate of 212 lbs N/acre. The corn hybrid Mycogen Seeds TMF2H918 (HX1, LL, RR2) was seeded on beds spaced 40 inches apart at a rate of 35,840 seeds/acre on 13 March 2012 in 66 rows 400 feet long. The corn hybrid Mycogen Seeds TMF2L844 (RR2) was planted in the east and west buffer on either side of the experiment as a non Bt refugia. Irrigation water was applied in furrows to wet the bed and germinate the seed on 14 March. Irrigation water was applied in alternate rows in the first four irrigations through 2 May to conserve water and push salt away from the seed line. Irrigation water timing and amount were estimated using soil moisture measurements with a neutron probe. Irrigation water was applied when 50% or less of the plant available water was depleted in the rooting zone, or about every week once the crop was established. The maximum rooting depth was assumed to be 1.2 m. Irrigation water application is presented in Table 1.

The soil type was a Casa Grande sandy loam to sandy clay loam. The soil contained 2.2 ppm NO_3-N and 3.1ppm NH_4-N in the top 5 ft of soil at planting time. The chemical characteristics of the surface 6 inches of soil are: 2.2 ppm NO_3-N, 3.1ppm NH_4-N, pH = 8.4, OM = 0.58, total exchange capacity = 18.44 meq/100 g, soluble sulfur = 33 ppm, Olsen phosphorus = 3 ppm P, Ca = 2762 ppm (74.89% base saturation), Mg = 225 ppm (10.17% base saturation), K = 345 ppm (4.80 base saturation), Na = 304 ppm (7.17 base saturation), other bases (3.00 base saturation), Fe = 4 ppm, Mn = 11ppm, Cu = 1.75 ppm, Zn = 0.69 ppm.

The experimental design was a randomized complete block with 2 treatments and 12 replications (randomized as six 2 x 2 latin squares) and duplicated in two irrigation blocks. The individual plots were 8 rows wide and about 50 feet long including a 6.7 ft alley. The Invinsa treatments were applied at the 11-12 leaf stage as follows: 1) control – not treated, 2) Invinsa applied at incipient stress on 15 May. The two irrigation blocks received adequate irrigation or deficit irrigation near the timing of the Invinsa application. For the deficit irrigation block, irrigation water was withheld for about 7 days past incipient stress. The deficit irrigation block received adequate water before and after the "stress period" in an amount similar to the adequate irrigation block. After the deficit irrigation period, the crop recovered and water use was similar to the adequate irrigation block.

The Invinsa was sprayed using a backpack spraying unit that consisted of a boom with four fan-type nozzles (Teejet 8002 EVS, ~500 mls/min at 20 psi) on 20 inch spacing and a 5 gallon tank pressurized by CO_2. The tank was filled with 4 gallons of water, 53.3 g of Invinsa (3.8% ai) was added to the water, and the mixture was stirred with a wooden lathe stake for several minutes. The tank was pressurized to 20 psi. The two outside rows of the plots (rows 1 and 8) were not sprayed and the rows next to the outside rows (rows 2 and 7) received a single pass of the spray whereas the other rows received two passes of the spray. Therefore, the effective area was calculated based on five rows instead of six. Two columns or half of each irrigation block was sprayed separately and a fresh batch of Invinsa was mixed for each block. About 2 gallons of solution was sprayed and 2 gallons of residual solution remained in the tank before discarding in preparation for mixture of a new batch. The details of the Invinsa application are presented in Table 2.

The number of fully expanded leaves was determined by counting exposed collars on three designated plants per plot. The 5^{th} and 10^{th} leaves on these plants were marked for ease of counting and to ensure that senesced leaves are accounted for.

Neutron access tubes were installed to a depth of 5 ft and the first neutron probe readings were taken on 22 April, and water use after this time was determined using neutron attenuation. Daily water use was calculated from the difference of neutron probe readings about 3 days post irrigation after drainage had occurred to the day of or 1 day

before the next irrigation. For much of the season, irrigations were applied weekly, so neutron probe readings were taken twice per week during this time.

Plants were sampled five times during the season for height, leaf area index, and yield of leaves, stalks, and ears. The ears were comprised of the kernels, cobs, and husks. The sampling area comprised 1 m of row, which included about 9 plants. Leaf area index and dry weight were determined from all the plants at the first sampling date. At subsequent sampling times, four plants were sub-sampled for leaf area index and moisture content. The moisture content was used to obtain the dry weight conversion for the fresh weight of the entire sample. Plant moisture content was determined by drying the samples in an oven at 65 ºC. Leaf area index was determined from a Li-Cor leaf area instrument.

Gas exchange was measured about 10 times during the season from 7 May to 28 May with a LiCor 6400 XT portable photosynthesis system corresponding to pre-Invinsa application, post-Invinsa application, and post-water stress time periods. On each day gas exchange measurements were taken, six readings were recorded per plot from three leaves and two sampling areas per leaf. Measurements were recorded for four replications of each treatment in the adequate and deficit irrigation blocks. The readings were taken about 1-2 m from the east alley for row 5 of each plot. Artificial light from the fluorescence chamber of the instrument was used rather than relying on sunlight. The protocol for using the instrument is as follows: 1) Both the desiccant and soda lime were changed every day the instrument was used, 2) Before going to the field for measurements, the instrument was prepared for use according to manufacturer's recommendations, 3) The flow rate is set to 250 mmol s^{-1}, the reference CO_2 is set to 380 ppm, the IRGAs are matched before each measurement, P quantum is set to 1800 μmol m^{-2} s^{-1}, and the area of the chamber is set. 4) Relative humidity is kept between 50 and 70% by adjusting with the desiccant. Readings were taken between 10:30 am and 2:30 pm. The LiCor 6400 XT portable photosynthesis system measures many variables, but only photosynthetic rate, conductance to water, intercellular CO_2 concentration, vapor pressure deficit, and leaf temperature were statistically analyzed.

Grain was harvested on 4 August from 15 ft of the center two rows of the plot for a total of 30 ft of row. The grain was shelled with a corn sheller, the kernel moisture content determined with an electronic moisture meter, and the cobs were dried in an oven at 65 ºC to obtain oven-dry cob weight.

Results and Discussion

The crop emerged on 26 March, silked and shed pollen between 31 May (adequate irrigation) and 1-2 June (deficit irrigation), and reached black layer around 28 July. The crop was planted in the middle of March which is about optimum for the area. The plants appeared robust and progressed well, but there were some differences in height that may have resulted from non-uniformity in water-run nitrogen application or from nitrogen deficiency. Overall, the growing season was warmer and wetter than normal (Table 3).

Invinsa had little or no effect on crop growth measured at five different dates during the growing season (Table 4). Invinsa compared to the control generally had no effect at the 5% probability level on leaf area index, plant height, plant moisture, leaf yield, stem yield, leaf plus stem yield, ear yield, and total yield. However, at the 14 June sampling time, we measured an increase in height and decrease in leaf, leaf plus stem, and total yield due to Invinsa application.

Invinsa had no effect on grain yield, grain moisture content, harvest index, ear number, kernels per ear, kernel weight, and silking date (Table 5). The grain yield for the adequately irrigated block averaged 1.97 t/a on a dry basis, which is equivalent to 83 bu/a on a 15.5% moisture basis. This grain yield is low compared to the total plant yield and can be explained by the low harvest index of about 35% instead of a more normal harvest index of around 50%. The total yield of 6.04 t/a at harvest averaged across treatments for the adequately irrigated block is equivalent to a yield of about 20 t/a on a 70% moisture basis, which is much less than the to the silage corn yields of 30 to 40 t/a obtained in this growing region.

Invinsa had some effect on daily water use, and these effects differed depending on the irrigation regime in some cases (Table 6). For the deficit irrigation regime, water use was decreased by Invinsa application from 5/25-5/29, but increased by Invinsa from 6/15-6/19. There may have been some bias in the deficit irrigation plots since water use was lower in the Invinsa plots from 5/11-5/15 before Invinsa was applied on 5/15. For the adequate irrigation regime, water use was increased by Invinsa application from 5/18-5/21, 5/25-5/29, 6/15-6/19, and 7/22-7/28. An

interaction between irrigation and Invinsa was measured from 5/18-5/21 and 5/25-5/29. The increase in daily water use due to Invinsa application is difficult to explain since we were not able to measure effects of Invinsa on dry matter and grain yield, nor on gas exchange properties of the leaf as will be discussed below.

We were not able to measure an effect of Invinsa on photosynthetic rate, conductance to water, intercellular CO_2 concentration, vapor pressure deficit, or leaf temperature (Table 7). Invinsa had no effect at individual measurement days, nor at pre-Invinsa or post-Invinsa or post-stress periods where the data was analyzed as repeated measures. An apparent response was evident at certain measurement times based on numerical values and ignoring statistical significance, but variability inherent in the measurements did not allow differences to be statistically significant.

The lack of a response this year to Invinsa, other than water use, is similar to the results from last year where no consistent response was measured. Invinsa has increased corn yield in other regions, and heat and/or water stress at the Maricopa may mask the effects of Invinsa or render it ineffective.

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Table 1. Irrigation dates in 2012 and amounts for the adequate and deficit irrigation blocks.

	Irrigation	
Date	Adequate	Deficit
	inches	
3/14	7.23	4.62
4/10	3.34	2.88
4/23	3.31	3.76
5/02	3.16	4.18
5/08	2.90	2.76
5/15	3.54	0.00
5/22	2.87	4.17
5/29	2.63	2.08
6/05	3.07	3.34
6/12	3.07	2.71
6/19	3.19	3.85
6/26	2.83	2.83
7/03	3.62	3.62
7/11	3.58	3.38
7/19	2.65	2.65
Sum	50.99	46.85

Table 2. Invinsa application gallonage, rates, and start and end times and temperatures for Invinsa applied on May 15, 2012. The target application was a volume of 2 gal, rate of 20 gal/acre, and rate ai of 10 g ai/acre.

Irrigation	Column	Rep	Volume	Rate	Rate ai	Start	End	Start	End
			gal	gal/acre	g ai/acre	time	time	º C	º C
Dry	1 & 2	1-6	1.79	18.0	9.11	7:38 am	7:51 am	22.4	22.4
	3 & 4	7-12	1.88	18.9	9.33	8:28 am	8:40 am	23.5	30.6
Wet	5 & 6	1-6	1.62	16.3	8.29	8:06 am	8:16 am	22.5	22.7
	7 & 9	7-12	1.77	17.8	8.74	8:58 am	9:04 am	37.4	42.9

Table 3. Mean daily maximum, minimum, and average temperature and the sum of monthly precipitation during the growing season in 2012 compared to normal.

	Maximum temperature		Minimum temperature		Average temperature		Precipitation	
Month	2012	Normal	2012	Normal	2012	Normal	2012	Normal
	º F						inches	
Apr	87	85	53	50	71	68	0.07	0.30
May	97	94	61	59	80	78	0.10	0.17
June	106	103	71	67	90	86	0.00	0.09
July	103	104	77	74	90	87	1.98	0.76
Average	98.3	96.5	65.5	62.5	82.8	79.8	---	---
Sum	---	---	---	---	---	---	2.15	1.32

Table 4. Effect of Invinsa on plant growth and development for corn grown with deficit or adequate irrigation in a trial conducted at Maricopa, AZ in 2012.

Date	Irrigation	Invinsa	Leaf area index	Leaf number	Plant height	Plant moisture	Leaf yield	Stem yield	Leaf+stem yield	Ear yield	Total yield
					inches	%	t/a	t/a	t/a	t/a	t/a
21-Apr	Deficit	No	---	5.2	17.3	---	---	---	---	---	---
		Yes	---	5.1	17.4	---	---	---	---	---	---
	Prob>F	Invinsa	---	0.6742	0.8202	---	---	---	---	---	---
	Adequate	No	---	5.3	17.3	---	---	---	---	---	---
		Yes	---	5.5	18.2	---	---	---	---	---	---
	Prob>F	Invinsa	---	0.1112	0.1624	---	---	---	---	---	---
	Avg	No	---	5.3	17.3	---	---	---	---	---	---
		Yes	---	5.3	17.8	---	---	---	---	---	---
		Invinsa	---	0.2429	0.1747	---	---	---	---	---	---
	Prob>F	Irr*Inv	---	0.1071	0.2577	---	---	---	---	---	---
7-May	Deficit	No	1.65	9.2	47.2	91.5	0.33	0.25	0.58	---	0.58
		Yes	1.52	9.1	47.0	90.8	0.33	0.26	0.59	---	0.59
	Prob>F	Invinsa	0.1850	0.2657	0.8743	0.1882	0.9851	0.7127	0.8310	---	0.8310
	Adequate	No	1.79	9.3	48.9	91.5	0.37	0.27	0.64	---	0.64
		Yes	1.56	9.2	48.8	91.0	0.39	0.30	0.69	---	0.69
	Prob>F	Invinsa	0.0728	0.7126	0.9553	0.0693	0.6055	0.3046	0.3974	---	0.3974
	Avg	No	1.72	9.2	48.1	91.5	0.35	0.26	0.61	---	0.61
		Yes	1.54	9.1	47.9	90.9	0.36	0.28	0.64	---	0.64
	Prob>F	Invinsa	0.0238	0.3509	0.8897	0.0422	0.6967	0.3270	0.4429	---	0.4429
		Irr*Inv	0.5437	0.7537	0.9631	0.7296	0.6789	0.6631	0.6394	---	0.6394
28-May	Deficit	No	3.45	16.4	75.5	81.6	0.98	2.16	3.14	---	3.14
		Yes	3.33	16.5	75.3	83.0	0.96	1.78	2.74	---	2.74
	Prob>F	Invinsa	0.6262	0.7545	0.8838	0.3989	0.6573	0.0600	0.0611	---	0.0611
	Adequate	No	3.94	17.8	88.9	82.3	1.15	2.63	3.78	---	3.78
		Yes	4.17	17.8	87.3	82.2	1.18	2.71	3.90	---	3.90
	Prob>F	Invinsa	0.4943	0.8751	0.3619	0.9526	0.6681	0.7893	0.7484	---	0.7484
	Avg	No	3.68	17.1	82.2	81.9	1.07	2.39	3.46	---	3.46
		Yes	3.75	17.1	81.3	82.6	1.07	2.25	3.32	---	3.32
	Prob>F	Invinsa	0.8051	1.0000	0.4573	0.5395	0.8972	0.4164	0.5063	---	0.5063
		Irr*Inv	0.3846	0.7764	0.5964	0.4894	0.5445	0.2070	0.2215	---	0.2215
14-Jun	Deficit	No	3.44	20.8	85.7	76.5	1.10	2.72	3.82	1.05	4.86
		Yes	3.39	20.9	87.1	76.3	1.10	2.78	3.88	0.91	4.79
		Invinsa	0.8433	0.3944	0.2851	0.9043	0.9914	0.8445	0.8724	0.2673	0.8855
	Adequate	No	4.06	21.1	98.8	76.5	1.34	3.72	5.06	1.44	6.50
		Yes	3.81	21.2	98.1	78.7	1.26	2.99	4.25	1.25	5.50
	Prob>F	Invinsa	0.3381	0.1753	0.5923	0.0454	0.2514	0.0146	0.0165	0.1242	0.0120

Date	Irrigation	Invinsa	Leaf area index	Leaf number	Plant height	Plant moisture	Leaf yield	Stem yield	Leaf+stem yield	Ear yield	Total yield
					inches	%	t/a	t/a	t/a	t/a	t/a
	Avg	No	3.75	20.9	92.2	76.5	1.22	3.22	4.44	1.25	5.71
		Yes	3.60	21.1	92.6	77.5	1.18	2.88	4.06	1.08	5.14
	Prob>F	Invinsa	0.3983	0.1274	0.7061	0.2783	0.3926	0.1009	0.1050	0.0532	0.0662
		Irr*Inv	0.5676	0.8619	0.2519	0.2343	0.3846	0.0586	0.0650	0.6950	0.1034
8-Jul	Deficit	No	1.98	---	---	66.9	0.65	2.20	2.85	3.14	5.99
		Yes	2.03	---	---	66.6	0.69	2.30	2.99	3.49	6.48
	Prob>F	Invinsa		---	---	0.6745	0.5411	0.5067	0.4229	0.2347	0.2167
	Adequate	No	2.16	---	---	67.4	0.77	2.67	3.44	3.64	7.09
		Yes	2.12	---	---	65.4	0.78	2.69	3.47	3.75	7.22
	Prob>F	Invinsa		---	---	0.1698	0.9121	0.9481	0.9373	0.7294	0.7797
	Avg	No	2.07	---	---	67.1	0.71	2.44	3.15	3.39	6.54
		Yes	2.07	---	---	66.0	0.74	2.49	3.23	3.62	6.85
	Prob>F	Invinsa	0.9534	---	---	0.1646	0.5691	0.7350	0.6585	0.2802	0.3319
		Irr*Inv	0.6685	---	---	0.3057	0.6599	0.8262	0.7629	0.5573	0.5735
4-Aug	Deficit	No	---	---	---	52.0	---	---	2.71	2.37	5.09
		Yes	---	---	---	54.1	---	---	2.58	2.87	5.45
	Prob>F	Invinsa	---	---	---	0.2158	---	---	0.5950	0.0421	0.2671
	Adequate	No	---	---	---	53.4	---	---	2.91	3.00	5.91
		Yes	---	---	---	52.1	---	---	3.16	3.00	6.16
	Prob>F	Invinsa	---	---	---	0.4240	---	---	0.3071	0.9905	0.6209
	Avg	No	---	---	---	52.7	---	---	2.81	2.68	5.50
		Yes	---	---	---	53.1	---	---	2.87	2.94	5.81
	Prob>F	Invinsa	---	---	---	0.7270	---	---	0.7531	0.2695	0.3030
		Irr*Inv	---	---	---	0.1539	---	---	0.2795	0.2783	0.8479
All	Deficit	No	2.63	12.9	56.4	73.6	0.77	1.83	2.62	1.32	3.92
		Yes	2.57	12.9	56.7	74.1	0.77	1.78	2.56	1.45	4.01
	Prob>F	Invinsa	0.8247	0.4302	0.7064	0.4309	0.9083	0.5499	0.4618	0.1297	0.5723
		Inv*Date	0.8437	0.8225	0.4280	0.4654	0.9283	0.2520	0.4659	0.1475	0.2599
	Adequate	No	2.99	13.4	63.5	74.2	0.91	2.32	3.17	1.62	4.78
		Yes	2.93	13.4	63.1	73.9	0.90	2.17	3.09	1.60	4.69
	Prob>F	Invinsa	0.9017	0.8355	0.4120	0.6692	0.7727	0.2871	0.5651	0.9120	0.6389
		Inv*Date	0.4465	0.5953	0.5568	0.2844	0.6102	0.1576	0.1257	0.7900	0.1630
	Avg	No	2.80	13.1	60.0	73.9	0.84	2.08	2.90	1.47	4.35
		Yes	2.75	13.2	59.9	74.0	0.84	1.98	2.82	1.53	4.35
	Prob>F	Invinsa	0.8168	0.5784	0.7686	0.6827	0.8999	0.2266	0.3744	0.4144	0.9332
		Irr*Inv	0.9095	0.8528	0.4003	0.3415	0.7746	0.5676	0.9312	0.3196	0.4784
		Inv*Date	0.7247	0.5692	0.3208	0.4740	0.7951	0.3726	0.4063	0.2404	0.1385
		Irr*Inv*Date	0.5275	0.7515	0.7663	0.2830	0.7357	0.0883	0.0993	0.7446	0.3476

Table 5. Effect of Invinsa on grain yield, components of yield, and silking date for corn grown with deficit or adequate irrigation in a trial conducted at Maricopa, AZ in 2012.

Irrigation	Invinsa	Grain yield	Grain moisture	Harvest Index	Ear number	Kernel number	Kernel weight	Silking date
		t/a	%	%	acre^{-1}	ear^{-1}	mg	
Deficit	No	1.63	7.98	34.9	31,291	249	189	6/01
	Yes	1.64	7.83	32.1	31,690	247	189	6/02
Prob>F	Invinsa	0.9792	0.6373	0.4760	0.6572	0.9500	0.9350	0.1748
Adequate	No	2.01	7.28	36.8	33,287	289	188	5/31
	Yes	1.93	7.17	33.6	32,380	281	188	5/31
Prob>F	Invinsa	0.7618	0.6615	0.4381	0.5509	0.7783	0.9592	1.0000
Avg	No	1.82	7.63	35.8	32,289	269	189	6/01
	Yes	1.78	7.50	32.9	32,035	264	188	6/01
Prob>F	Invinsa	0.6025	0.3850	0.1084	0.6139	0.6566	0.8655	0.1219
	Irr*Inv	0.5598	0.8944	0.8966	0.2017	0.7650	0.9517	0.1219

Table 6. Effect of Invinsa on average daily water use for various time periods for corn grown with deficit or adequate irrigation in a trial conducted at Maricopa, AZ in 2012. The first time period of 5/11-5/15 is before the Invinsa application on 5/15.

		Average daily water use											
Irrigation	Invinsa	5/11-5/15	5/18-5/21	5/25-5/29	6/2-6/4	6/8-6/11	6/15-6/19	6/22-6/25	6/29-7/2	7/6-7/9	7/14-7/16	7/22-7/28	Avg*
		inches/day											
Deficit	No	0.41	0.21	0.33	0.33	0.33	0.31	0.33	0.36	0.35	0.31	0.21	0.31
	Yes	0.34	0.15	0.23	0.30	0.27	0.33	0.34	0.35	0.38	0.26	0.20	0.28
	Invinsa	0.0066	0.1632	0.0440	0.5194	0.3005	0.0169	0.9470	0.7893	0.1457	0.4568	0.9275	0.7049
Adequate	No	0.45	0.38	0.31	0.35	0.33	0.41	0.35	0.33	0.39	0.31	0.19	0.33
	Yes	0.46	0.52	0.38	0.39	0.33	0.44	0.38	0.43	0.52	0.54	0.25	0.42
	Invinsa	0.9082	0.0318	<.0001	0.5915	0.9060	0.0227	0.6320	0.5596	0.1337	0.0721	<.0001	0.0857
Avg	No	0.43	0.30	0.32	0.34	0.33	0.36	0.34	0.34	0.37	0.31	0.20	0.32
	Yes	0.40	0.33	0.31	0.34	0.30	0.39	0.36	0.39	0.45	0.40	0.22	0.35
	Invinsa	0.0151	0.2880	0.5949	0.9682	0.3649	0.0444	0.7216	0.2689	0.2218	0.1883	0.3502	0.3529
	Irr*Inv	0.8321	0.0086	0.0067	0.3521	0.2718	0.1750	0.7752	0.4776	0.8653	0.0447	0.4622	0.2194

* Avg does not include the time period from 5/11-5/15.

Table 7. Effect of Invinsa on photosynthesis and associated measurements for corn grown with deficit or adequate irrigation in a trial conducted at Maricopa, AZ in 2012.

Treatment period	Date	Irrigation	Invinsa	Photo-synthetic rate	Conduct-ance to water	Inter-cellular CO_2	Vapor pressure deficit	Leaf temperature
				µmol CO_2 m^{-2} s^{-1}	mol m^{-2} s^{-1}	µmol CO_2 mol air^{-1}	kPa	ºC
Pre-Invinsa	7-May	Deficit	No	46.6	0.278	65.0	2.25	35.0
			Yes	44.4	0.249	52.9	2.41	35.3
		Prob>F	Invinsa	0.4049	0.2320	0.4005	0.4716	0.7927
		Adequate	No	43.8	0.271	91.5	2.30	34.3
			Yes	46.9	0.337	96.4	2.21	34.1
		Prob>F	Invinsa	0.2675	0.1643	0.8525	0.7122	0.7899
		Avg	No	45.2	0.275	78.3	2.28	34.6
			Yes	45.6	0.293	74.6	2.31	34.7
		Prob>F	Invinsa	0.8460	0.4675	0.8047	0.7902	0.9693
			Irr*Inv	0.1987	0.0687	0.5618	0.3783	0.6832
Pre-Invinsa	11-May	Deficit	No	43.5	0.269	80.5	2.19	31.9
			Yes	43.5	0.306	113.3	2.05	31.6
		Prob>F	Invinsa	0.9836	0.1033	0.1275	0.2004	0.4136
		Adequate	No	44.2	0.389	152.1	2.16	31.7
			Yes	42.7	0.334	127.6	2.27	32.0
		Prob>F	Invinsa	0.5095	0.2034	0.2107	0.0169	0.2831
		Avg	No	43.9	0.329	116.3	2.18	31.8
			Yes	43.1	0.320	120.5	2.16	31.8
		Prob>F	Invinsa	0.6168	0.6524	0.7207	0.7446	0.9510
			Irr*Inv	0.6332	0.0493	0.0405	0.0398	0.1900
Pre-Invinsa	14-May	Deficit	No	38.6	0.247	92.1	2.75	32.1
			Yes	41.9	0.284	104.1	2.69	32.1
		Prob>F	Invinsa	0.0160	0.0004	0.1680	0.5538	0.9960
		Adequate	No	38.4	0.275	104.5	3.00	31.8
			Yes	38.7	0.287	109.1	2.98	31.6
		Prob>F	Invinsa	0.8930	0.5896	0.7496	0.9190	0.6665
		Avg	No	38.5	0.261	98.3	2.87	32.0
			Yes	40.3	0.285	106.6	2.84	31.9
		Prob>F	Invinsa	0.1179	0.0413	0.3352	0.6473	0.6509

Treatment period	Date	Irrigation	Invinsa	Photo-synthetic rate	Conduct-ance to water	Inter-cellular CO_2	Vapor pressure deficit	Leaf temperature
				µmol CO_2 m^{-2} s^{-1}	mol m^{-2} s^{-1}	µmol CO_2 mol air^{-1}	kPa	ºC
			Irr*Inv	0.1773	0.2795	0.6642	0.7722	0.6512
Post-Invinsa	15-May	Deficit	No	25.1	0.277	208.0	1.05	32.1
			Yes	25.6	0.279	214.4	0.99	31.9
		Prob>F	Invinsa	0.7228	0.8826	0.5184	0.1219	0.4407
Post-Invinsa	16-May	Deficit	No	26.6	0.146	51.6	3.99	32.0
			Yes	29.4	0.156	43.9	3.96	32.0
		Prob>F	Invinsa	0.1915	0.4653	0.5026	0.7139	0.8935
Post-Invinsa	17-May	Deficit	No	24.1	0.137	74.7	4.24	33.2
			Yes	28.3	0.172	69.8	4.17	33.0
		Prob>F	Invinsa	0.6283	0.4831	0.8600	0.8054	0.8518
Post-Invinsa	18-May	Deficit	No	20.7	0.103	35.4	4.16	32.1
			Yes	16.8	0.087	57.9	4.29	32.4
		Prob>F	Invinsa	0.3905	0.4723	0.1268	0.5359	0.5034
		Adequate	No	39.6	0.223	51.4	3.72	31.5
			Yes	38.9	0.244	83.2	3.44	30.2
		Prob>F	Invinsa	0.8056	0.5345	0.3684	0.3010	0.2283
		Avg	No	30.1	0.163	43.4	3.94	31.8
			Yes	27.8	0.162	70.5	3.86	31.3
		Prob>F	Invinsa	0.3897	0.8352	0.1574	0.6291	0.3760
			Irr*Inv	0.5423	0.3806	0.7909	0.2190	0.1553
Post-Invinsa	21-May	Deficit	No	9.0	0.066	178.1	3.87	32.1
			Yes	7.1	0.057	200.2	3.71	31.4
		Prob>F	Invinsa	0.6728	0.7730	0.7020	0.3974	0.3660
		Adequate	No	32.0	0.221	112.3	3.37	31.9
			Yes	36.3	0.254	110.6	3.35	32.0
		Prob>F	Invinsa	0.3944	0.4213	0.5857	0.7705	0.2840
		Avg	No	20.5	0.143	145.2	3.62	32.0
			Yes	21.7	0.156	155.4	3.53	31.7
		Prob>F	Invinsa	0.7509	0.6380	0.7180	0.3978	0.4371
			Irr*Inv	0.4075	0.4377	0.6738	0.5107	0.2555

Treatment period	Date	Irrigation	Invinsa	Photo-synthetic rate	Conduct-ance to water	Inter-cellular CO_2	Vapor pressure deficit	Leaf temperature
				µmol CO_2 m^{-2} s^{-1}	mol m^{-2} s^{-1}	µmol CO_2 mol air^{-1}	kPa	ºC
Post-stress	25-May	Deficit	No	33.7	0.246	125.4	2.80	29.7
			Yes	37.9	0.241	88.3	3.18	31.6
		Prob>F	Invinsa	0.2578	0.9043	0.1539	0.2167	0.0696
		Adequate	No	36.7	0.283	121.9	2.75	30.7
			Yes	38.6	0.283	129.8	2.62	30.2
		Prob>F	Invinsa	0.5488	0.9086	0.7142	0.6402	0.6268
		Avg	No	35.2	0.265	123.7	2.78	30.2
			Yes	38.3	0.261	109.1	2.90	30.9
		Prob>F	Invinsa	0.1896	0.9900	0.3323	0.5183	0.3165
			Irr*Inv	0.5946	0.8555	0.1553	0.1990	0.0937
Post-stress	28-May	Deficit	No	31.8	0.163	34.2	4.13	32.3
			Yes	33.5	0.184	44.4	4.01	31.9
		Prob>F	Invinsa	0.5868	0.3365	0.3873	0.3669	0.4767
		Adequate	No	35.4	0.223	65.9	3.60	30.9
			Yes	35.4	0.211	64.3	3.85	32.0
		Prob>F	Invinsa	0.9873	0.7626	0.9033	0.3836	0.3146
		Avg	No	33.6	0.193	50.0	3.86	31.6
			Yes	34.4	0.198	54.4	3.93	32.0
		Prob>F	Invinsa	0.7588	0.8357	0.5641	0.6853	0.4616
			Irr*Inv	0.7388	0.4839	0.4369	0.2596	0.2150
Pre-Invinsa	Avg	Deficit	No	42.2	0.262	82.0	2.43	32.6
			Yes	43.0	0.286	97.5	2.38	32.5
		Prob>F	Invinsa	0.8002	0.1025	0.2642	0.9011	0.9878
			Inv*Date	0.0782	0.0046	0.0005	0.0159	0.7465
		Adequate	No	41.8	0.321	121.0	2.52	32.3
			Yes	41.9	0.316	114.0	2.54	32.2
		Prob>F	Invinsa	0.6400	0.6074	0.3713	0.9715	0.8475
			Inv*Date	0.3118	0.0123	0.1381	0.4294	0.5316
		Avg	No	42.0	0.291	101.5	2.48	32.4
			Yes	42.5	0.301	105.8	2.46	32.4
		Prob>F	Invinsa	0.5992	0.1787	0.5561	0.9347	0.8705

Treatment period	Date	Irrigation	Invinsa	Photo-synthetic rate	Conduct-ance to water	Inter-cellular CO_2	Vapor pressure deficit	Leaf temperature
				µmol CO_2 m^{-2} s^{-1}	mol m^{-2} s^{-1}	µmol CO_2 mol air^{-1}	kPa	ºC
			Irr*Inv	0.8795	0.6440	0.1382	0.8998	0.9159
			Inv*Date	0.2880	0.1933	0.5722	0.7404	0.9147
			Irr*Inv*Date	0.0992	0.0004	0.0017	0.0343	0.2154
Post-Invinsa	Avg	Deficit	No	21.1	0.146	109.5	3.46	32.3
			Yes	21.4	0.148	117.2	3.42	32.2
		Prob>F	Invinsa	0.9250	0.8416	0.5980	0.6826	0.2571
			Inv*Date	0.0247	0.6138	0.3715	0.5098	0.5451
		Adequate	No	35.8	0.222	81.9	3.55	31.7
			Yes	37.6	0.249	96.9	3.40	31.1
		Prob>F	Invinsa	0.2778	0.2365	0.4058	0.3910	0.2924
			Inv*Date	0.0701	0.7512	0.0449	0.1198	0.0704
		Avg	No	25.3	0.168	101.6	3.49	32.1
			Yes	26.0	0.176	111.4	3.42	31.9
		Prob>F	Invinsa	0.7533	0.2933	0.4974	0.3377	0.2717
			Irr*Inv	0.8882	0.2469	0.7570	0.4903	0.5057
			Inv*Date	0.2906	0.1480	0.1819	0.9973	0.9884
			Irr*Inv*Date	0.7684	0.9946	0.2130	0.0181	0.0083
Post-stress	Avg	Deficit	No	32.7	0.203	79.8	3.46	31.0
			Yes	35.7	0.212	66.4	3.59	31.7
		Prob>F	Invinsa	0.3282	0.7648	0.1357	0.4771	0.2006
			Inv*Date	0.2965	0.2032	0.0029	0.0032	0.0009
		Adequate	No	36.1	0.253	93.9	3.18	30.8
			Yes	37.0	0.246	97.1	3.23	31.1
		Prob>F	Invinsa	0.7766	0.8852	0.7781	0.7395	0.5581
			Inv*Date	0.4014	0.6688	0.6819	0.1264	0.1006
		Avg	No	34.4	0.228	86.9	3.32	30.9
			Yes	36.3	0.229	81.7	3.41	31.4
		Prob>F	Invinsa	0.3726	0.9209	0.4363	0.4618	0.1627
			Irr*Inv	0.6353	0.7583	0.2249	0.7716	0.5553
			Inv*Date	0.1814	0.7792	0.1720	0.6938	0.7187
			Irr*Inv*Date	0.8595	0.3024	0.0415	0.0035	0.0016