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Effect of herbicides and different sowing distances on maize growth indicators.

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ABSTRACT

The experiment was conducted in the experimental field of the College of Agricultural Engineering Sciences / Salahalddin University-Erbil (SUE) (Erbil Governorate) during the fall season of 2023, aiming to evaluate the maize crop growth and controlling the accompanying weeds, using two herbicides and their combination under different planting distances. The experiment was implemented based on a randomized complete block design (RCBD) in a split-plot arrangement with three replicates. Plant densities (66,600, 57,100, and 50,000 plants.ha^{-1}) occupied the main plots, and the weed control treatments (Nicosulfuron @ 48g.ha-1, Metribuzin @ 400 g.ha-1, Nicosulfuron @ 48g.ha-1 + Metribuzine @ 400 g.ha-1, weedy, and weed-free) occupied the sup-plots. The results showed that the plant density 66600 plants.ha-1 was superior, exhibiting the lowest average weed density 90 days after sowing, the highest weed index, and the highest crop growth rate, reaching 9.80 plants.m-2, 26.13%, and 3.56 g.m-2.day, respectively, compared with the plant density of 50000 plants.ha-1, which gave the highest weed density of 13.04 plants m-2 and the lowest averages of the weed index and crop growth rate, attaining 36.45% and 3.23 plants.m-2.day-1, respectively, yet it was superior by recording the least number of days to reach tasseling and silking (51.80 and 57.33 days, respectively), compared with the plant density of 66600 plants.h-1, which took a longer number of days to reach tasseling and silking. The results also showed that the herbicide Nicosulfuron was superior in giving the best results, as it recorded the lowest average weed density after 90 days, the best weed index, the best crop growth rate, and the lowest number of days to 50% tasseling and silking (6.44 plants.m-2, 11.78%, and 3.71 g.m-2.days-1, 51.66 days, and 57.22 days, respectively) compared to the control treatment, which recorded the highest weed density (33.22 plants.m-2) and the lowest averages of the other traits above (62.78%, 1.88 grams.m-2.day, 55.88 days, 62.22 days, respectively).

***Keywords*:** Maize, herbicides, weed index, Nicosulfuron, CGR.

INTRODUCTION

Weeds are considered one of the most important pests that spread in the crop fields, causing dramatic losses, amounting to approximately 70% of strategic crops [1], [2], [3]. An increase in weed density can negatively impact crop productivity by reducing biological activities. Weeds compete with crops for essential growth requirements, particularly space. This competition becomes more critical during the crucial growth stages, leading to a decline in grain yield. Therefore, it is essential to study plant densities and suggest new planting spacing to limit the spread of weeds. Following integrated weed management has many benefits, as using several methods to weed control may give satisfactory results in control rates; however, chemical control remains one of the most essential modern agricultural techniques and is one of the best methods used due to its ease of application and high efficiency. Attention must be paid to controlling the accompanying weeds to achieve a significant increase in the maize growth indicators because of this crop's economic importance, as maize occupies third place in terms of economic significance after wheat and rice, as a result of the fact that it contains a significant percentage of protein, estimated at 9%, in addition to containing a high rate of carbohydrates estimated at 70% and the oil percentage estimated at 4% [4], [5]. The use of the herbicides Belldozer120 and Amaze80 led to the control of the broad and narrow-leaved weeds accompanying maize and exhibited the minimum number of days for tasselling and silking [6]. It was also noticed that the herbicide Dinko, at a spray rate of 400 ml. ha^{-1}, was significantly superior in controlling the narrow and broad-leaved weeds, reducing them at the flowering stage. The herbicide efficiency was equal at 400 and 300 ml. ha^{-1} concentrations in most growth traits [7]. Hence, this research aimed to evaluate the maize crop performance under different sowing distances using several herbicides to determine the best plant density and herbicide combination to obtain the best weed index and crop growth indicators.

Material and methods

The experiment was conducted in the experimental field of the College of Agricultural Engineering Sciences / Salahaddin University-Erbil (SUE) (Erbil Governorate), located at 29° norths and 29° east during the fall season of 2023 to evaluate the maize crop growth and use two herbicides to control the accompanying weeds under different sowing distances. The experiment was implemented based on the randomized complete block design (RCBD) in a split-plot arrangement with three replicates.

The experiment included the following treatments:

First factor: planting at different row spacing (represents the main plots), including:

1- Planting at 60cm row spacing constitutes a plant density of 66600 plants. ha^{-1}.
2- Planting at 70cm row spacing constitutes a plant density of 57100 plants. ha^{-1}
3- Planting at 80cm row spacing constitutes a plant density of 50000 plants. ha^{-1}

Second factor: weed control treatments (represents the subplots)

No	Herbicide	Use rate	Active ingredient
1	Nicosulfuron	48 $g.h^{-1}$	Rimsulfuron
2	Metribuzin	400 $g.h^{-1}$	Metribuzin
3	Nicosulfuron + Metribuzine	48+ 400 $g.h^{-1}$	-
4	Weedy	0.0	-
5	Weed free	0.0	-

The soil service practices were conducted as the soil was plowed with a mold-board plow, loosened with disc harrows, and leveled with a leveler. The experimental land was divided into 12 m^2 plots dimensioned 3 x 4 m. Seeds of the Nahrin variety were sowed on 7/20/2023. Urea fertilizer (46% N) was added at a rate of 400 kg. ha^{-1} in two batches; the first was added 20 days after sowing and the second a month after the first batch, and the whole amount of DAP fertilizer at a rate of 320 $kg.ha^{-1}$ was added at sowing [8]. Also, the maize stalk borer was controlled with 10% granular Diazinon insecticide at a rate of 6 kg.ha-1 as a drill in the plant in two batches; the first was 20 days after emergence, and the second batch was 15 days after the first one. The crop was irrigated whenever necessary, and the plants were harvested after they reached full maturity on 11/10/2023.

Studied traits

Weed traits involving;

1- Weed species and density ($plants.m^{-2}$) were identified and calculated 90 days after spraying by counting the number of weeds per square meter for each experimental unit [9].

Types of weeds growing in the experiment.

English name	Scientific name	Family	Type	Life cycle	Degree of density
Johnson grass	*Sorghum halepense* L.	Poaceae	Narrow-leaf	Perennial	Very dense
Field bind weed	*Convolvulus arvensis* L.	Convolvulaceae	Broad-leaf	Perennial	Very dense
Bur weed	*Xanthium stramarium* L.	Compositae	Broad-leaf	Annual	Middle
Prospis	*Lagonychium farctum* L.	Fabaceae	Broad-leaf	Perennial	A little
Prickly alhagi	*Alhagi maurorum* L.	Fabaceae	Broad-leaf	Perennial	A little
Nut grass	*Cyperus rotaundus* L.	Cyperaceae	Narrow-leaf	Perennial	A little
European Heliotrope	*Heliotropium Europaeum* L.	Boraginaceae	Broad-leaf	Annual	A little
Black nightshade	*Solanum nigrum* L.	Solanaceae	Broad-leaf	Annual	A little

2- Weed index: It was calculated according to the following equation [10].

$$weed\ index = \frac{grain\ yield\ of\ the\ weed\ free\ treatment - grain\ yield\ of\ the\ weed\ control\ treatment}{grain\ yield\ of\ the\ weedfree\ treatment}\ x\ 100$$

3- Crop growth rate (CGR) ($g.m^2.day^{-1}$): It was calculated according to the following equation:

$$CGR = 1/GA \times (W2 - W1)/(T2 - T1)$$

Where:

GA: The area of land occupied by the plant

W1: Plant sample dry weight at the first period T1

W2: Plant sample dry weight at the second period T2

4- Number of days to 50% tasselling: It was counted from the first irrigation time until the tasselling appeared in 50% of the plants for each experimental unit [11].
5- Number of days to 50% silking: It was counted from the first irrigation time until the silking appeared in 50% of the plants for each experimental unit.

Statistical analysis:

Data were statistically analyzed as a randomized complete block design (RCBD) within a split plots arrangement, and the means were compared based on the least significant difference (L.S.D) at the probability level of 5% [12]. Using the software GENSTAT.

Results and discussion

1- Weed density 90 days after spraying (plants.m^{-2})

Results in Table 1 refer to significant differences in the weed density trait 90 days after spraying affected by the plant densities. The plant density of 66600 plants. ha^{-1} achieved the lowest weed density of 9.80 plants.m^{-2}, compared with the plant density of 50000 plants.ha^{-1}, which exhibited the highest weed density, averaging 13.04 plants.m^{-2}. The increase in the number of crop plants per unit area constituted competition among the crop plants and between the crop and the weed plants, and the high densities of crop plants helped the crop compete with the weeds and reduce their numbers.

Table 1 also indicates that weed control treatments affected the weed density (plants.m^{-2}). The treatment of the herbicide Nicosulfuron achieved the lowest weed density 90 days after spraying, attaining 6.44 plants.m^{-2}, compared with the highest weed density average of 33.22 plants.m^{-2} attained by the control treatment. The reason for reducing weed density when treated with the herbicide may be its effectiveness in inhibiting some bioactivities within the plant, as Nicosulfuron inhibits amino acids' synthesis, which inhibits the enzyme Aceto Lactate Synthase (ALS). This enzyme takes part in synthesizing the branched amino acids Leucine, Isoleucine, and Valine. These amino acids are necessary for constructing and manufacturing proteins to produce new cells and new specialized tissues, thus enhancing the normal growth of plants [13]. Inhibition caused by the ALS enzyme results in abnormal growth of the weeds, represented by stunting, yellowing, tissue death, and gradual death, which leads to inhibiting and eliminating the weed growth. This result was consistent with what was found by [7]. who found that using chemical herbicides reduced the density of the weeds accompanying maize crops.

The interaction between the two study factors significantly affected the trait 90 days after spraying. The used herbicides behave positively by reducing weed density at all plant densities compared to the control treatment, which behaves negatively under the effect of different plant densities.

Table 1. Effect of different treatments on the weed density trait (plants.m-2) 90 days after spraying.

treatments of weed control	Plant densities (Plant.ha^{-1})			Mean
	66600	57100	50000	
Nicosulfuron	4.78	6.22	8.33	6. 44
Metribuzin	8.22	9.11	10.56	9.30
Nico.+ Metr.	7.78	8.22	8.44	8.15
Weedy	28.22	33.56	37.89	33.22
Weed free	0.0	0.0	0.0	0.0
L.S.D$_{0.05}$		1.72		0.73
Mean	9.80	11.42	13.04	
L.S.D$_{0.05}$		1.59		

2- Weed index

Table 2 illustrates significant differences between the treatments of the studied factors and their interactions in the weed index trait. The plant density of 66600 plants. ha^{-1} recorded the best weed index of 26.13%, compared with the plant density of 50000 plants. ha^{-1}, recording the highest weed index of 36.45%. The highest weed index Recorded by the plant density of 50000 plants. ha^{-1} denotes the highest loss in grain yield in the presence of weeds, as a reflection of the increase in weed density caused by the treatment (Table 1), and a decrease in the weed control percentage, reflected in a grain yield reduction.

Weed control treatments recorded a significant difference in controlling weeds. The herbicide Nicosulfuron treatment exhibited the lowest weed index of 11.78% compared with the weedy treatment, which had the highest weed index average, reaching 62.78%. The effectiveness of the herbicide Nicosulfuron in controlling accompanied weeds was evident in reducing

weed densities (Table 1), which led to obtaining the best weed control percentages, which helped the crop exploit growth requirements, increasing its grain yield.

Concerning the interaction treatments, the treatment of the herbicide Nicosulfuron at the plant density of 66600 plants. ha^{-1} recorded the lowest weed index, attaining 4.41%; in contrast, the weedy treatment at the plant density of 50000 plants. ha^{-1} recorded the highest weed index, reaching 65.90%, which did not differ significantly from the interaction between the weedy treatment and the plant density of 57100 plants.ha^{-1}, which recorded a weed index of 64.62%.

Table 2. Effect of different treatments on the weed index trait (%)

treatments of weed control	Plant densities (Plant.ha^{-1})			Mean
	66600	57100	50000	
Nicosulfuron	4.41	11.07	54.80	11.78
Metribuzin	44.10	47.69	54.80	48.86
Nico.+ Metr.	24.31	38.27	41.66	34.75
Weedy	57.82	64.62	65.90	62.78
Weed free	0.0	0.0	0.0	0.0
$L.S.D_{0.05}$		3.85		2.00
Mean	26.13	32.33	36.45	
$L.S.D_{0.05}$		3.00		

3- Crop growth rate ($g.m^{-2}.day^{-1}$)

Results in Table 3 refer to significant differences between the plant density treatments in this trait. The plant density treatment of 66600 plants. ha^{-1} recorded the highest crop growth index, reaching 3.56$g.m^{-2}.day^{-1}$; in contrast, the treatment of 50000 plants. ha^{-1} recorded the lowest crop growth rate of 3.23 $g.m^{-2}.day^{-1}$. The number of plants per unit area is an influential factor in increasing the plant biomass per unit area and for the superiority of the same treatment in weed competition by giving the lowest weed density (Table 1) and the highest weed index (Table 2), dramatically impacts in making room for the crop to grow without competition and perform bioactivities, including photosynthesis and carbon assimilation in the best way.

The table also reveals significant differences between herbicide treatments for weed control. The herbicide Nicosulfuron was significantly superior, recording the highest crop growth rate, averaging 3.71 $g.m^{-2}.day^{-1}$, compared with the control treatment that recorded the lowest crop growth rate of 1.88$g.m^{-2}.day^{-1}$. The reason behind the higher accumulation of dry matter when treated with herbicides may be due to their effectiveness in reducing weed density (Table 1) and increasing the weed index (Table 2), which allows the crop to optimally exploit growth requirements, which was reflected positively in increasing its growth indicators and prompted the plant to increase carbon assimilation rates and dry matter accumulation.

We also notice from the table significant differences between the treatments of the interaction between the study factors. The interaction treatment of the herbicide Nicosulfuron with the plant density of 50000 plants. ha^{-1} recorded the highest crop growth rate, attaining 4.05$g.m^{-2}.day^{-1}$, simultaneously, the weedy treatment when interacted with the plant density of 50000 plants.ha-1 recorded the lowest crop growth rate of 1.57$g.m^{-2}.day^{-1}$, confirming that weeds compete with the crop more than the competition among the same crop plants

Table 3. Effect of different treatment on the crop growth rate ($g.m^{-2}.day^{-1}$)

treatments of weed control	Plant densities (Plant.ha^{-1})			Mean
	66600	57100	50000	
Nicosulfuron	3.83	3.25	4.05	3.71
Metribuzin	2.94	3.88	3.67	3.49
Nico.+ Metr.	3.65	3.69	2.60	3.31
Weedy	1.87	2.20	1.57	1.88
Weed free	4.22	4.77	4.27	4.42

$L.S.D_{0.05}$		0.09		0.05
Mean	3.30	3.56	3.23	
$L.S.D_{0.05}$		0.05		

4- Days to 50% tasseling

Results in Table 4 demonstrate the significant differences between the plant density treatments. The treatment of 50000 plants. ha^{-1} recorded the least number of days to reach the tasseling stage (51.80 days), compared with the plant density of 66600 plants. ha^{-1}, which needed the highest number of days to reach the tasseling, recording 52.37 days, and did not differ significantly from the plant density treatment of 57100 plants. ha^{-1}, which recorded 52.40 days. The reason for the decrease in the number of days from sowing to reach 50% tasseling at the plant density of 50,000 plants. ha^{-1} is the abundance of light and the lack of competition between the crop plants, which increases the temperatures falling on the ground and thus increases the plant's accumulative heat, which encourages plants to perform the bioactivities and physiological processes to reach inflorescence stage earlier.

We also observe significant differences between the treatments of herbicides used to control weeds. Treatment of controlling weeds with the herbicide Nicosulfuron took the least period to reach 50% tasseling, recording 51.667 days, followed by the weed-free treatment, which recorded 48.778 days, compared with the weedy treatment that took the longest period of 55.889 days to reach the 50% tasseling. Needing the weedy treatment, the most extended period of days to reach tasseling was a result of the increased weed density in this treatment (Table 1) and the increased competition of the weed of this treatment for the main growth requirements, the most important of which are nutrients, which led to a delay in the plant's biological and physiological processes required for the plant to reach inflorescence. These results are consistent with [6].

The interaction between the two study factors also resulted in significant differences in the trait. The weed-free treatment interacted with all plant densities, exhibiting the least number of days to reach 50% tasseling, as well as the herbicide treatments behaved similarly compared with the weedy treatment that behaved negatively in delaying the number of days required to reach 50% tasseling that differed according to the plant densitie

Table 4. Effect of different treatments on the trait of the number of days to 50% tasseling

treatments of weed control	Plant densities (Plant.ha^{-1})			Mean
	66600	57100	50000	
Nicosulfuron	51.33	52.00	51.66	51.66
Metribuzin	52.66	52.00	53.66	52.77
Nico.+ Metr.	51.66	53.00	52.66	52.44
Weedy	56.00	56.33	55.33	55.88
Weed free	47.33	48.66	50.33	48.77
$L.S.D_{0.05}$		1.03		0.62
Mean	51.80	52.40	52.73	
$L.S.D_{0.05}$		0.62		

5- Days to 50% silking

Results in Table 5 show significant differences between the treatments in the days taken to reach 50% silking. The treatment of 50000 plants. ha^{-1} recorded the lowest average of this trait (57.33 days), differing significantly from the density of 66600 plants. ha^{-1}, which recorded the most significant number of days to reach 50% silking (58.39 days), did not differ significantly from the plant density of 57100 plants. $ha^{-1,}$ which recorded 58.533 days. The delay in silking at high plant density (66,600 plants per. ha^{-1}) may be due to a shadowing increase among plants, which induced the vegetative growth and delayed silking.

Concerning controlling weeds with herbicides, we also found significant differences between the treatments. Treating with the herbicide Nicosulfuron took the least number of days, recording 57.222 days, preceded only by the weed-free treatment, which recorded 55.22 days to reach 50% silking; in contrast, the weedy treatment recorded the most extended periods, taking 62.33 days to reach 50% silking. The superiority of the same treatment in controlling weeds by reducing their density and recording the best weed index (Tables 1 and 2) allowed the crop to optimally and greatly exploit the space, light intensities, nutrients, and moisture, which appeared clearly in improving the crop growth indicators. These results are consistent with [6].

The results of the interaction treatments between the two study factors also show significant differences. Treatment with herbicides in general, and with Nicosulfuron in particular, and the weed-free treatment recorded the lowest number of days to reach silking at different plant densities, in contrast to the performance of the weedy treatment, as it behaved negatively with all densities, recording the highest number of days to reach silking.

Table 5. Effect of different treatments on the number of days to 50% silking

treatments of weed control	Plant densities (Plant.ha^{-1})			Mean
	66600	57100	50000	
Nicosulfuron	57.33	57.33	57.00	57.22
Metribuzin	57.66	58.00	60.33	58.66
Nico.+ Metr.	57.33	59.33	59.00	58.55
Weedy	62.00	62.66	62.33	62.33
Weed free	54.33	55.33	56.00	55.22
L.S.D$_{0.05}$		0.82		0.42
Mean	57.73	58.53	58.93	
L.S.D$_{0.05}$		0.64		

Conclusions

From the study, we conclude that weeds played a primary role in competing with the crop for the growth requirements that affected the maize growth indicators, including increasing the number of days to reach 50% of both tasseling and silking, as well as affecting the dry matter accumulation rate per unit area, which seemed evident in the trait of the crop growth rate. Plant density difference also played a secondary role in affecting crop growth indicators.

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تأثير مبيدات الأدغال و مسافات الزراعة المختلفة في مؤشرات نمو الذرة الصفراء.

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الخلاصة

نفذت تجربة حقلية في الحقل التجريبي التابع لكلية علوم الهندسة الزراعية /جامعة صلاح الدين (محافظة اربيل) خلال الموسم الخريفي للعام 2023 بهدف تقييم نمو محصول الذرة الصفراء ومكافحة الادغال المرافقة له باستخدام مبيدي ادغال وخليطهما تحت مسافات زراعة مختلفة. طبقت التجربة وفق تصميم القطاعات الكاملة المعشاة بترتيب الالواح المنشقة بثلاث مكررات ،اذ احتلت الكثافات النباتية (66600 و 57100 و 50000 نبات .هـ – 1) الالواح الرئيسية ، واحتلت معاملات المكافحة*Nicosulfuro)* 48 غم.هـ –1 و *Metribuzin 400* غم.هـ– 1 و *Nicosulfuron + Metribuzine48 + 400* غم.هـ–1و*weedy* و*weed free*) الالواح الثانوية .أظهرت النتائج تفوق الكثافة النباتية 66600 نبات .هـ–1 باعطائها اقل متوسط لكثافة الادغال بعد 90 يوم واعلى دليل ادغال واعلى معدل نمو محصول بلغ 9.80 نبات . م–2 و26.13% 3.56 غم . م–2. يوم–1 على التوالي قياساً بالكثافة النباتية 50000 نبات .هـ–1 التي اعطت اقل المتوسطات للصفات نفسها والتي بلغت 13.04 نبات .م–2 و 36.45 % 3.23 نبات .م–2 .يوم–1 على التوالي الا انها تفوقت باعطاء اقل عدد ايام للوصول للتزهير الذكري والانثوي(51.80 و 57.33 يوم) قياساً بالكثافة النباتية 66600 نبات .هـ–1 التي استغرقت عدد ايام اطول للوصول الى التزهير الذكري والانثوي. كذلك أظهرت النتائج تفوق المبيد *Nicosulfuron* بأعطاء افضل النتائج أذ اعطى اقل متوسط لكثافة الادغال بعد 90 يوم وافضل دليل ادغال وافضل معدل نمو محصول واقل عدد ايام حتى 50% تزهير ذكري وانثوي (6.44 نبات .م–2 و 11.78 % و 3.71 غم .م–2 يوم–1 و 51.66 يوم و57.22 يوم على التوالي) قياسا مع معاملة المقارنة التي اعطت اقل المتوسطات للصفات اعلاه (33.22 نبات .م–2 و 62.78 % و1.88غم .م–2. يوم–1 و 55.88 يوم و 62.22 يوم).

الكلمات المفتاحية : الذرة الصفراء ، مبيدات الادغال ، دليل الادغال ، نيكوسلفورون ،معدل نمو المحصول.