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EASILY PRACTICABLE PACKAGES FOR WEED MANAGEMENT IN MAIZE

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ABSTRACT

The individual effect of several weed control practices are well known, but limited information is available on the response of maize (*Zea mays* L.) cultivars to integrate such control practices. Field experiments were conducted in 2011 and 2012 to evaluate the best and least cost weed management strategies for maize production. Treatments included three weed control practices, namely hoeing twice 25 and 40 DAS, metribuzin+hoeing once 40 DAS and a weedy check; three maize cultivars, Giza 128, Giza 310 and Giza 329; and two planting row configurations (single rows and twin rows). Hoeing twice and metribuzin+hoeing once caused reductions in weed dry weight of 90.5 and 70%, respectively. Hoeing twice was the most effective practice for maize plant height, leaf area index (LAI), kernels number ear^{-1}, and grain yield. Poor transmition of light beneath canopy of Giza 329 plants was observed, which recorded the maximum height compared to other cultivars. Giza 128 was superior for producing 100 kernels weight and grain yield. Maize plants intercepted more light and produced higher LAI in twin rows than single ones; with no variations in weed dry weight, plant height, kernels number ear^{-1}, 100 kernel weight and grain yield. Metribuzin+hoeing once x Giza 128 x single rows favoured increased grain yield.

Key Words: Metribuzin, plant row configuaions, weed control, *Zea mays*

RÉSUMÉ

L'effet individuel de plusieurs pratiques de désherbage sont bien connus, mais peu d'informations sont disponibles sur le contrôle des mauvaises herbes dans le maïs (*Zea mays* L.) et de la réponse de cultivars de maïs à l'intégration entre ces pratiques. Les expériences de terrain ont été menées pendant 2011 et 2012 pour évaluer les meilleures et moins stratégies de gestion des mauvaises herbes sur les coûts de gestion du maïs. Les traitements comprenaient trois pratiques de contrôle des mauvaises herbes, à savoir binage deux fois 25 et 40 JAS, metribuzin+binage fois 40 JAS et un chèque de mauvaises herbes; trois cultivars de maïs; Giza 128, Giza 310 et Giza 329 et deux configurations de lignes de plantation (lignes simples et des lignes jumeaux). Les résultats ont suggéré que deux fois en train de sarcler et métribuzine+binage une fois causé des réductions dans la biocénose des mauvaises herbes de 90.5 et 70 %, respectivement. Binage deux fois a été les plus efficaces grains de hauteur, LAI, pratique pour augmenter le maïs plante numéro oreille^{-1}, et grain céder ha^{-1}. Mauvaise transition de lumière sous couvert de plantes de Giza 329 a été observée, qui a enregistré la hauteur maximale par rapport aux autres cultivars. Giza 128 est le cultivar supérieur pour produire 100 poids d'amandes et grain céder ha^{-1}. Les plants de maïs ont intercepté plus de lumière et produit LAI plus élevé dans les rangées de lits jumeaux que seul ceux qui, sans variation dans la biomasse des mauvaises herbes, la hauteur des plantes, noyaux numéro oreille^{-1}, poids de 100 grains et grain céder ha^{-1}. Métribuzine+binage une fois x Giza 128 x rangées simples ont montré un impact favorable pour augmenter le grain céder.

Mots Clés: Métribuzine, la géométrie de l'usine, le contrôle des mauvaises herbes, *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop in Egypt; unfortunately, weed proliferation threaten its yields. Reductions in maize yield in Egypt due to weed infestation range from 70-90 % (Abouziena *et al*., 2007; Abd EL-Samad *et al*., 2012). Weed management strategies need to be developed to maintain or increase the sustainability of maize production.

Besides mechanical practices, the use of weed-competitive cultivars and plant geometrical distribution are some of the non-chemical strategies that could help in suppressing weeds by closing the canopy quickly and increasing shade on the weeds (Chauhan *et al*., 2012), since competition for light is an important factor in crop-weed interference (competition and allelopathy).

Maize plants have an open canopy, especially at the early stages, thus encountering severe competition from weeds for light and other environmental resources. Through light deprivation in the early stages of growth, less solar energy is available to crop plants for photosynthesis and, hence, growth, yield and quality will be reduced. So, managing weeds is essential.

In this regard, manual and cultural weed management methods are remarkable, especially under sustainable agriculture conditions, where the agro-chemicals are not applied. Herein, hoeing is still a conventional weed control in row spacing crops, but hand labour is becoming scarce and wages have been increased. Modification of plant geometry by choosing the optimal plant distribution as a cultural weed control, with potentiality, might be considered. Optimum crop geometry is one of the important factors for higher production, by efficient utilisation of under ground resources and also harvesting as much as solar radiation and, in turn, better photosynthate formation (Thavaprakaash *et al.,* 2005).

Spatial distribution of the crop canopy may be important for weed suppression, but literature on this subject for maize on the associated weeds is scarce. Information on the response of canopy components to changes in plant spatial arrangement and the basis for light attenuation changes under different row spacing is lacking (Flénet *et al*., 1996; Westgate *et al*., 1997).

This study was, therefore, conducted to determine the effect of integrating weed management (hoeing twice or metribuzin+hoeing once with plant geometrical distribution) on some maize hybrids productivity and the associated weeds.

MATERIALS AND METHODS

The study was conducted at the Research and Experimental Station, Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate (30°192 N, 31°162 E), Egypt, during summer seasons of 2011 and 2012. The experimental site soil was clay loam, with 1.15 % organic matter, 0.14 % total nitrogen and P^H of 7.52. The preceding crop was wheat in both seasons.

Treatments and experimental design. Treatments included: (a): three weed control treatments were tested: hoeing twice (at 25 and 40 days after sowing (DAS)), metribuzin+hoeing once 40 DAS, and a weedy check. Metribuzin, 70% WP at a rate of 0.72 kg ha^{-1} was sprayed on the soil surface (pre-emergence) immediately before sowing. A knapsack sprayer was used, with one nozzle boom and in 480 litres water ha^{-1}; (b): three cultivars: one Single cross (Giza 128) and two Three-Way crosses (Giza 310 and Giza 329) were obtained from Agricultural Research Centre, Giza Governorate, Egypt and used in this study; and (c): two planting row configurations: maize grains were sown in single rows (one side of the ridge with 25 cm-hill distance) and twin rows (two sides of the ridge with 50 cm-hill distance). It is noted that the two planting row configurations produce the same plant density (about 5.7 plants m^{-2}).

The experiment was established in a randomised complete design in a split-split plot arrangement, with four replicates. The main plots included weed control treatments; sub-plots were for three maize hybrids; and the sub-sub plots occupied by plant geometry patterns. The experimental plot area was 14.7 m^2 and contained 6 ridges (3.5 m length and 0.7 m apart).

Grains of maize hybrids were drilled at a rate of 24 kg ha^{-1}. At 25 DAS, plants were thinned to one plant $hill^{-1}$. All other recommended crop husbandry practices were adopted throughout the two seasons.

Sampling and assessments

Light intensity. At 80 DAS, light intensity was measured at noon between 12-14 hr on clear day (using lux meter LX-101) at 50 cm height from the soil surface. In this respect, three observations were recorded from each plot under the canopy of maize plants, and then the average of these three readings was calculated.

Weed dry weight. Weeds of one square meter from the middle ridge of each plot were hand pulled at 80 DAS, and total weeds' dry weight was estimated. The dry weight was recorded after air drying for 8 days and oven drying at 105° C for 24 hours.

Maize plant parameters. Plant height and LAI of maize were measured at 80 DAS. LAI was measured by calculation the ratio between plant total leaf area and the land area occupied by the plant (Watson, 1952), leaf area in maize is calculating according to Dwyer and Stewart (1986) as follow:

Leaf area = L × W × A

Where:

L, W, and A are leaf length, leaf maximum width and a constant (A = 0.75), respectively. At harvest, ten plants were chosen randomly from each plot to measure kernel number ear^{-1} and 100-kernel weight. Whole plants of each plot were harvested to estimate grain yield ha^{-1}.

Statistical analysis. The data from each season were analysed using analysis of variance according to Gomez and Gomez (1984). The combined analysis of variance for the data of the two seasons was performed after testing the error homogeneity and LSD at 0.05 level was used for the comparison between treatment means.

RESULTS AND DISCUSSION

During both growing seasons the dominant annual broad leaf weeds were common purslane (*Portulaca oleracea*, L.) and malta jute (*Chorchorus olitorius* L.); while the major grasses were jungle rice (*Echinochloa colonum* (L.) Link.) and crowfoot grass (*Dactyloctenium aegyptium* (L.) P. Beauv.). The four weed species represented about 41, 19, 28 and 12 %, respectively, of total weeds in weedy check plots.

Such survey show that the association of multi weed flora (broad leaf and grassy weeds) with maize plants emphasized the need for application of integrated practices that effectively broaden the weed spectrum managed. The differences in abundant weed percentages could be attributed to their diversity of soil seed bank.

Weed control practices. Weed control had significant ($P<0.05$) effects on light intensity, weed dry weight, plant height, LAI, kernels ear^{-1}, 100 kernels weight and grain yield ha^{-1} of maize (Table 1). Plots treated with metribuzin+hoeing once recorded the lowest value of light intensity due to reduction in transmitted light beneath maize plants. Hoeing twice, along with metribuzin+hoeing once, caused reductions in weed dry weight reaching, 90.5 and 70%, respectively, compared to weedy check. Moreover, hoeing twice was the most effective practice for increasing maize plant height, LAI, kernels number ear^{-1}, and grain yield ha^{-1} (Table 1). There was no significant difference between hoeing twice and metribuzin+hoeing once in 100 kernels weight.

It is interesting to note that hand hoeing twice had a wider spectrum for weed elimination than metribuzin alone, whereas hoeing twice was more effective than metribuzin herbicide against total weeds in maize (El-Metwally *et al*., 2009). So, the addition of one extra hoeing with metribuzin, significantly increased its efficiency against maize weeds dry weight (Table, 1). However, metribuzin largely controls annual broad leaf and some grasses. The herbicide is absorbed through roots from soil and is translocated to shoots; and inhibits photosynthesis resulting in blocking electron transport leading to stopping CO_2

TABLE 1. Maize and weed data under the influence of weed management, maize cultivar and plant geometry in Egypt

Variables	Light intensity (lux)	Weed dry weight (g m^{-2})	Plant height (cm)	LAI	Kernels ear^{-1}	100 kernels weight (g)	Grain yield (t ha^{-1})
Weed control							
Hoeing twice	103.8	46.8	281.5	5.61	500.9	24.4	7.89
Metribuzin+hoeing once	83.7	113.7	277.8	5.49	487.9	24.1	7.61
Weedy check	396.1	495.4	265.8	4.15	370.5	22.4	5.23
$LSD_{0.05}$	14.0	77.8	5.1	0.65	27.4	1.9	0.91
Cultivar							
Giza 128	199.3	215.5	261.8	5.20	474.5	25.7	8.31
Giza 310	225.6	263.9	270.3	5.23	431.8	22.1	5.80
Giza 329	158.7	176.5	293.1	4.82	452.9	23.2	6.61
$LSD_{0.05}$	34.0	NS	10.2	NS	32.5	1.7	0.93
Plant geometry							
Single	267.2	253.0	271.4	4.87	441.9	23.3	6.53
Twin	121.8	184.2	278.7	5.30	464.2	23.9	7.29
$LSD_{0.05}$	44.3	NS	NS	0.27	NS	NS	NS

LAI = Leaf area index, NS = non-significant

fixation and production of ATP and $NADPH_2$ (WSSA, 1994).

The enhancement in maize yield and its components might be attributed to the higher efficiency of weed control treatments (hoeing twice or metribuzin+hoeing once) in weed elimination that enables crop plants to make good use of environmental resources; thus, increasing the competitiveness of maize plants against weeds. In addition, hoeing improves soil structure, aeration, water penetration and the availability of some nutrients for crop plants. These results are in agreement with those reported by Abouziena *et al*. (2007), Ahmed *et al*. (2008) and EL-Metwally *et al.* (2009)

Maize cultivars. There were significant ($P<0.05$) variations among maize cultivars in light intensity, plant height; kernels number ear^{-1}, 100 kernels weight and grain yield (Table, 1). On the contrary, weed dry weight and LAI were not affected. In this regard, poorly transmitted light beneath canopy of Giza 329 plants was obtained with a cultivar that recorded the maximum height compared to other cultivars. Also, Giza 128 was the superior cultivar for kernels ear^{-1}, 100 kernels weight and grain yield; but statistically equaled with Giza 329 in kernels ear^{-1}.

These results suggest that the studied maize cultivars are varied in canopy architecture, with concomitant effect on light attenuation. This may be due to their variability in plant height, leaf number, vertical leaf angle and leaf area density distribution along the main stem (Stewart and Dwyer, 1993; Maddonni and Otegui, 1996). Also, studied maize cultivars differed in yield potentiality; however they were similar in competitive ability against weeds since they had no adverse effect on weed dry weight (Table 1).

Silva *et al*. (2010) demonstrated that there was no difference in above-ground dry biomass of the weeds in the plots of the evaluated maize cultivars. Cardina (1995) reported that more competitive cultivars are not necessarily high yielding. Although Giza 329 was superior in light interception to Giza 128, it seems the latter had higher potentiality for light utilisation since it recorded higher grain yield.

Plant geometry. Significant differences between single rows and twin rows in light intensity and LAI were observed (Table 1). Maize plants intercepted more light and produced higher LAI in twin rows than single ones. This result reflects lowering intra-row competition for light among maize plants grown in twin rows. Optimal plant distribution reduces intra-row competition for solar radiation, water, nutrients and growth development (Karlen *et al*., 1987). Although, these differences were not enough to cause distinctive variations in weed dry weight, plant height, kernels number ear^{-1}, 100 kernels weight and grain yield ha^{-1}. Nelson (2007) in Missouri and Bruns *et al*. (2012) in mid south concluded that corn yield of single and twin-row production was similar. Increased interception of solar radiation during early growth may increase plant size; however, the plant is not able to store photosynthate for use during pollination and grain fill, which may be why increased early-season interception of solar radiation does not translate into increased yield for twin-row pattern. Elmore and Abendroth (2007) stated that if 95% of solar radiation is intercepted at flowering, regardless of row spacing, a row configuration change would not increase yield. Additionally, Gifford and Jenkins (1982) suggest that a row configuration change and the accompanying altercation in canopy architecture do not influence productivity due to maize's relatively linear photosynthetically active radiation response curve up to full sun.

Weed control x maize cultivars. There were significant interaction effects ($P<0.05$) between weed control treatments and maize cultivars on light intensity, weed dry weight, plant height, LAI, kernels number ear^{-1}, 100 kernels weight and maize grain yield (Tables 2 and 3). In plots hoed twice or treated with metribuzin+hoeing once, Giza 329, Giza 128 and Giza 310 caused reductions in weed dry weight amounted to 87.8-82.3, 78.8-82.1 and 55.0-71.4 %, respectively; compared with weedy check. Giza 128 and Giza 329 cultivars intercepted more sunlight in plots treated with hoeing twice or metribuzin+hoeing once resulting in the lowest light intensity beneath the plant canopy, compared with the weedy check. So, weeds received less light and grew weakly; thus producing poor dry weight.

The tallest maize plants were obtained with hoeing twice x Giza 329; while the maximum LAI value was obtained with hoeing twice x Giza 310. Moreover, with weeded practices, Giza 128 secured the maximum kernels ear^{-1}, 100 kernels weight and grain yield.

These results may mainly be due to the effective elimination of weeds using hoeing twice or metribuzin+hoeing once that enabled maize cultivars to grow well and made them have competitive advantage against weeds, producing high values of yield and its components. Many researchers reported that keeping maize cultivar plots weed free till 42 DAS and gave low weed dry matter, more vigorous plants and supported the production of higher grain yield. Farhadi-Afshar *et al*. (2009) reported that Shimmer cultivar exhibited superior traits over KSC403 cultivar by producing the highest grain yield under weeds fully controlled conditions. Also, Abouziena *et al*. (2013) found that the integration between herbicides plus hoeing once and hoeing twice x single cross 164 cultivar were the potent treatments for controlling weeds and enhancing grain yield in yellow maize.

Weed control x plant geometry. Hoeing twice x twin rows interaction showed the lowest light intensity and weed dry weight, as well as the highest values of LAI, kernels ear^{-1}, weight of 100 kernels and maize grain yield (Tables 2 and 3). The tallest maize plants were produced with hoeing twice x single rows. In contrast, the highest light intensity and weed dry weight, and the lowest values of plant height, LAI, kernels ear^{-1}, weight of 100 kernels and maize grain yield were recorded in weedy check with single rows. Coupling weed elimination using well weed control practice such as hoeing twice as well as increasing LAI and light interception due to well plant spatial distribution such as twin rows, may be the reason for decreasing weed dry weight and improving maize yield and its components. Earlier canopy closure and increased shading of weeds has been associated with increased crop competitiveness, reduced weed growth and increased grain yield (Dalley *et al*., 2004;

TABLE 2. Light intensity and weed dry weight in maize as influenced by the first order interaction between weed control, cultivars and plant geometry in Egypt

Variables		Light intensity (lux)	Weed dry weight (g m^{-2})
Weed control x cultivar			
Hoeing twice	Giza 128	91.3	22.2
	Giza 310	175.5	86.7
	Giza 329	44.5	31.6
Metribuzin+hoeing once	Giza 128	75.0	59.8
	Giza 310	111.3	195.6
	Giza 329	64.8	85.7
Weedy check	Giza 128	431.5	564.4
	Giza 310	390.0	509.4
	Giza 329	366.8	412.4
$LSD_{0.05}$		58.9	220.2
Weed control x plant geometry			
Hoeing twice	Single	121.3	62.2
	Twin	86.2	31.5
Metribuzin+hoeing once	Single	80.5	176.7
	Twin	86.8	50.7
Weedy check	Single	599.7	520.2
	Twin	192.5	470.6
$LSD_{0.05}$		76.6	197.8
Cultivar x plant geometry			
Giza 128	Single	233.3	263.3
	Twin	265.2	167.7
Giza 310	Single	336.2	354.9
	Twin	115.0	172.9
Giza 329	Single	232.0	140.9
	Twin	85.3	212.1
$LSD_{0.05}$		76.6	197.8

Abouziena *et al*., 2008). Altering row spacing influences interception of solar radiation and weed control (Teasdale, 1995).

Maize cultivars x plant geometry. Poor light intensity was recorded under the canopy of Giza 329 plants planted in twin rows (Table, 2). On the other hand, weed dry weight showed the lowest value with Giza 329 x single rows. In twin rows, Giza 329 and Giza 310 produced the highest values of plant height and LAI, respectively (Table, 3). Also, Giza 128 x single rows was the potent practice for achieving the highest kernels ear^{-1}, weight of 100 kernels and grain yield ha^{-1} (Table 3). Due to variation among the tested maize cultivars in plant height and LAI under different plant arrangement, in addition to their different genetic expression, the leaf orientation may be affected and reflected on light interception.

TABLE 3. Growth, yied and yield components of maize as influenced by the first order interaction between weed control, cultivars and plant geometry in Egypt

Variables		Plant height (cm)	LAI	Kernels ear^{-1}	100 kernels weight (g)	Grain yield (t ha^{-1})
Weed control x cultivar						
Hoeing twice	Giza 128	263.8	5.61	503.8	27.1	9.18
	Giza 310	274.3	5.80	472.3	22.6	6.55
	Giza 329	306.5	5.41	426.4	23.4	7.94
Metribuzin+hoeing once	Giza 128	260.3	5.40	505.1	25.4	8.86
	Giza 310	274.3	5.73	502.2	22.6	7.12
	Giza 329	299.0	5.34	456.3	24.3	6.86
Weedy check	Giza 128	261.3	4.58	414.7	24.4	6.89
	Giza 310	262.5	4.16	320.7	20.9	3.75
	Giza 329	273.8	3.70	375.9	21.9	5.05
$LSD_{0.05}$		17.6	0.92	64.7	1.83	1.37
Weed control x plant geometry						
Hoeing twice	Single	287.2	5.47	499.1	23.9	7.61
	Twin	275.8	5.75	502.6	24.9	8.16
Metribuzin+hoeing once	Single	275.5	5.42	473.8	23.8	7.19
	Twin	280.2	5.56	501.9	24.4	8.04
Weedy check	Single	251.5	3.71	352.7	22.3	4.78
	Twin	280.2	4.58	388.2	22.5	5.67
$LSD_{0.05}$		14.3	0.47	61.3	2.35	1.44
Cultivar x plant geometry						
Giza 128	Single	263.7	5.05	477.6	26.3	8.46
	Twin	259.8	5.34	471.4	25.0	8.16
Giza 310	Single	270.3	5.00	408.2	20.6	4.79
	Twin	270.3	5.46	455.3	23.5	6.82
Giza 329	Single	280.2	4.55	439.8	23.1	6.33
	Twin	306.0	5.09	465.9	23.3	6.90
$LSD_{0.05}$		14.3	0.47	61.3	2.35	1.44

LAI = Leaf area index

Under rectangular planting patterns, maize canopies with leaves perpendicular to rows may present higher efficiency of light attenuation than similar canopies where plants have a random leaf orientation (Maddonni *et al*., 2001). Ottman and Welch (1989) reported that hybrid x row configuration interaction suggesting that a difference in interception of solar radiation was greatest with hybrids characterised by upright leaf habits. Significant effects of interaction

Figure 1. (a) Light intensity, (b) weed dry weight, (c) plant height and (d) LAI of maize as influenced by weed control x cultivars x plant geometry in Egypt.

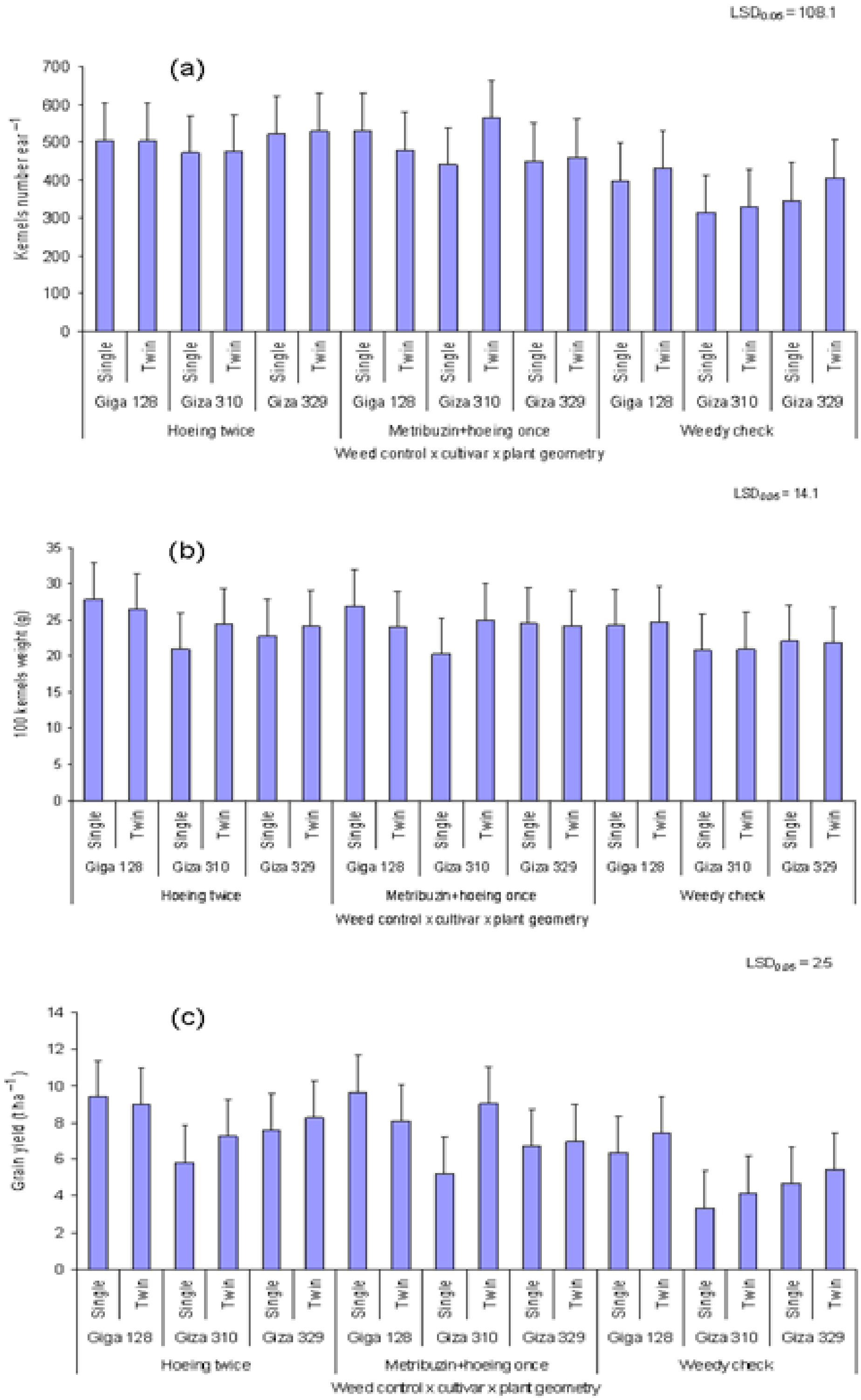

Figure 2. (a) Kernels ear $^{-1}$, (b) 100 kernels weight and (c) grain yield of maize as influenced by weed control x cultivars x plant geometry in Egypt.

between maize genotypes x plant spatial distributions on 200-kernel weight and grain yield were stated by Ahmed *et al.* (2011).

Weed control x cultivars x plant geometry. Second order interaction among weed control x cultivars x plant geometry had a remarkable effect on light intensity, weed dry weigh, plant height, LAI, kernels ear^{-1}, weight of 100 kernels and maize grain yield (Figs. 1 and 2). Without weed control (in weedy check plots), Giza 329 was the best cultivar for intercepting light and producing the tallest plants (in twin rows); and the lowest weed dry weigh (in single rows). Giza 128 x twin rows recorded the maximum LAI, kernels ear^{-1}, weight of 100 kernels and grain yield. Contrasting performances of maize cultivars under weeded treatments with plant geometry patterns were observed. However, under hoeing twice with twin rows, Giza 329 and Giza 128 secured the minimum values of light intensity and weed dry weigh, respectively (Figs. 1 and 2). With application of metribuzin+hoeing once, Giza 329 x twin rows and Giza 310 x single rows showed the highest plant height and LAI values, respectively. Moreover, the maximum kernels ear^{-1} was produced with metribuzin+hoeing once x Giza 310 x twin rows. The most effective interactions for increasing weight of 100 kernels and grain yield were hoeing twice x Giza 128 x single rows and metribuzin+hoeing once x Giza 128 x single rows. These findings may be due to that the agricultural practices i.e. weed control and plant geometry can manipulate the behavior of growth and yield of maize cultivars and their competitive ability against weeds.

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REFERENCES

Abd El-Samad, G.A., El-Bially, M.E. and Saudy, H.S. 2012. Response of maize and associated weeds to weed management and nitrogen rates. *Journal of Biological Chemistry and Environmental Sciences* 7 (4): 342-358.

Abouziena, H.F., Ahmed, M.A., Eldabaa, M.A.T. and Abd El Wahed, M.S.A. 2013. A comparative study on the productivity of two yellow maize cultivars grown under various weed control management. *Middle East Journal of Agriculture Research.* In press.

Abouziena, H.F., El-Karamany, M.F., Singh, M. and Sharma, S.D. 2007. Effect of nitrogen rates and weed control treatments on maize yield and associated weeds in sandy soils. *Weed Technology* 21: 1049-1053.

Abouziena, H.F., El-Metwally, I.M. and El-Desoki, E.R. 2008. Effect of plant spacing and weed control treatments on maize yield and associated weeds in sandy soils. *American-Eurasian Journal of Agricultural & Environmental Sciences* 4 (1): 9-17.

Ahmed, H.E., Dawood, R.A., Galal, A.H. and Abd El-Rahman, K.A. 2011. Effect of spatial distribution of plants and irrigation intervals on the yield and its components of two maize hybrids. *Assiut Journal of Agricultural Science* 42:94-105.

Ahmed, S.A., Shams, H.M., EL-Metwally, I.M., Shehata, M.N. and EL-Wakeel, M.A. 2008. Efficiency of some weed control treatments on growth, yield and its attributes of maize (*Zea mays* L.) plants and associated weeds. *Journal of Agricultural Sciences, Mansoura University* 33 (7): 4777-4789.

Bruns, H.A., Ebelhar, M.W. and Abbas, H.K. 2012. Comparing single-row and twin-row corn production in the mid south. *Crop Management.* doi:10.1094/CM-2012-0404-01-RS.

Cardina, J. 1995. Biological Weed Management. In: Hand Book of Weed Management Systems. Smith , A.E. (Ed.) Marcel Dekker, Inc. New York, Basal, Hong Kong. pp. 286.

Chauhan, B.S., Singh, R.G. and Mahajan, G. 2012. Ecology and management of weeds under conservation agriculture: a review. *Crop Protection* 38:57-65.

Dalley, C.D., Kells, J. and Renner, K. 2004. Effect of glyphosate application timing and row spacing on corn (*Zea mays*) and soybean (*Glycine max*) yields. *Weed Technology* 18: 165-176.

Draper, N.R. and Smith, H. 1998. Applied Regression Analysis, 3rd Ed. John Wiley & Sons, New York, USA. pp. 736.

Dwyer, L.M. and Stewart, D.W. 1986. Leaf area development in field-grown maize. *Agronomy Journal* 78: 334-343.

El-Metwally, I. M., Saudy, H.S. and El-Ashry, S.M. 2009. Response of maize and associated weeds to irrigation intervals, weed management and nitrogen forms. *Journal of Agricultural Sciences, Mansoura University* 34 (5): 5003-5017.

Elmore, R.W. and Abendroth L.J. 2007. Row spacing alternatives in corn. In row spacing alternatives in corn. Indiana CCA conference proceedings, Indianapolis, IN. 2007. Purdue University, West Layfayette, IN.

Farhadi-Afshar, H.R., Madani, H. Shirzadi, M.H. and Najafi, I. 2009. Study of effects of cultivar, weeds and plant density on yield and yield components of sweet corn under Iranian warm environment. *Plant Ecophysiology* 3: 103-108.

Flénet, F., Kiniry, J., Board, J., Westgate, M. and Reicosky, D.C. 1996. Row spacing effects on light extinction coefficients of corn, sorghum, soybean and sunflower. *Agronomy Journal* 88: 185-190.

Gifford, R.M. and Jenkins, C.L.D. 1982. Prospects of applying knowledge of photosynthesis toward improving crop production. pp. 419-457. In: Govindjee, N.M. (Ed.). Photosynthesis: Development, Carbon Metabolism, and Plant Productivity. Vol. 2. Academic Press, New York.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agriculture Research. A Wiley-Inter Science Publication, John Wiley & Sons, Inc. New York, USA.

Karlen, D.L., Kasperbauer, M.J. and Zublena, J.P. 1987. Row-spacing effects on corn in the southeastern U.S. *Applied Agriculture Research* 2: 65-73.

Maddonni, G.A, Chelle, M., Drouet, J.L., Andrieu, B. 2001. Light interception of contrasting azimuth canopies under square and rectangular plant spatial distributions: simulations and crop measurements. *Field Crop Research* 70:1-13.

Maddonni, G.A. and Otegui, M.E. 1996. Leaf area, light interception and crop development in maize. *Field Crop Research* 48:81-87.

Nelson, K.A. 2007. Glyphosate application timings in twin- and single-row corn and soybean spacings. *Weed Technology* 21:186-190.

Ottman, M.J. and Welch, L.F. 1989. Planting patterns and radiation interception, plant nutrient concentration, and yield in corn. *Agronomy Journal* 81:167-174.

Salah, S.A., Ahmed, M.A., Al-Kordy, M.A. and Magda Shalaby, A.F. 2011. Genetic analysis of energy production in yellow maize hybrids cultivated in newly cultivated sandy land. *Australian Journal of Basic and Applied Sciences* 5 (5): 104-114.

Silva, P.S.L., Silva, K.M.B. Silva, P.I.B. Oliveira, V.R. and Ferreira, J.L.B. 2010. Green ear yield and grain yield of maize cultivars in competition with weeds. *Planta daninha*, 28 no.1.

Stewart, D.W. and Dwyer, L. M. 1993. Mathematical characterization of maize canopies. *Agricultural and Forest Meterology* 66: 247-256.

Teasdale, J.R., 1995. Influence of narrow row/high population corn (*Zea mays*) on weed control and light transmittance. *Weed Technology* 9:113-118.

Thavaprakaash, N., Velayudham, K. and Muthukumar, V.B. 2005. Effect of crop geometry, intercropping systems and integrated nutrient management practices on productivity of baby corn (*Zea mays* L.) based intercropping systems. *Research Journal of Agricultural and Biological Sciences* 1: 295-302.

Watson, D.J. 1952. The physiological basis of variation in yield. *Advances in Agronomy* 4: 101-145.

Westgate, M. E., Forcella, F., Reicosky, D.C. and Somsen, J. 1997. Rapid canopy closure for maize production in US corn belt: Radiation use efficiency and grain yield. *Field Crop Research* 49:249-258.

WSSA (Weed Science Society of America), 1994. Herbicide Handbook 7th Ed. Champaign, Illinois, USA.