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POSSIBILITIES OF REDUCING HERBICIDE DOSES THROUGH NARROWED ROW SPACING AND USE OF ADJUVANT IN MAIZE (*Zea mays* L.)

Muhammad Ather Nadeem[1], Asif Tanveer, Tasawer Abbas* and Fahad Bashir

ABSTRACT

Adjuvants have significant role in decreasing the herbicide cost and environmental damage by reducing the herbicides dose. Field experiments were conducted at Agronomic Research Area, University of Agriculture Faisalabad, to assess the possibilities of reducing herbicide dose through narrowed row spacing and use of adjuvants on weeds in maize. The experiment comprised of nicosulfuran + atrazine + propisochlor (pre-mixed formulation) at label dose (740 g a.i ha^{-1}); 75% (555 g a.i ha^{-1}) and 50% (370 g a.i ha^{-1}) alone and in combination with alkyl ether sulphate at 400 ml ha^{-1} as adjuvant along with weedy check in maize sown at 60 cm (narrowed rows) and 75cm (recommended) row spacing. The results exhibited that narrow row spacing caused significant reduction in weed biomass and weed density without any negative impact on grain yield of maize. The most effective treatment in controlling weed, reducing the dry matter of weed and increasing maize grain yield were nicosulfuran + atrazine + propisochlor at 555 g a.i. ha^{-1} (75% of recommended) with adjuvant and nicosulfuran + atrazine + propisochlor at 740 g a.i ha^{-1} (recommended dose). The results revealed that the dose of nicosulfuran + atrazine + propisochlor can be reduced upto 25% by addition of alkyl ether sulphate as adjuvant.

Key words: Adjuvant, narrow row spacing, nicosulfuran + atrazine + propisochlor, post emergence herbicides, maize, weeds.

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INTRODUCTION

Maize (*Zea mays* L.) is one of the main cereal grain crops in the world due to its food and feed value. In Pakistan, it is most commonly grown crop after harvesting wheat and rice. However, average yield of

[1]Dept. of Agronomy, University of Agriculture, Faisalabad, Pakistan.
*Corresponding author's email: tagondaluaf@gmail.com

maize in Pakistan is 4,155 kg ha^{-1} that is much lower than potential yield of the available maize varieties in Pakistan (Govt. of Pakistan, 2015). Among yield reducing factors to maize, weed infestation is of prime importance. Excessive growth of weeds in maize field leads to 66% to 80% reduction in crop yield (Adigun, 2001). Herbicides have been used very effectively for controlling weeds in maize (Khan and Haq, 2004 and Juhl, 2004). However, herbicide use is facing challenges due to environmental and health hazards and development of herbicide resistance against commonly used herbicides in maize (Owen and Zelaya, 2005). There is dire need to reduce the herbicide usage by using lower doses of herbicides to overcome these hazards. Reduced herbicide doses decrease risk of crop injury, environmental hazards, herbicide carryover phytotoxicity problems and the increasing problem of herbicide-resistant weeds (Blackshaw *et al.,* 2006; Pannacci and Covarelli, 2009). However, herbicides use at reduced doses may lead to herbicide hormesis in weeds or crop plants (Abbas *et al.,* 2015, 2016a; Nadeem *et al.,* 2016). Therefore, use of adjuvants is essential to ensure acceptable weed control efficacy of herbicides at reduced doses. Adjuvants are the most important ingredients in the formulation of biological activity. Valuable effect of adjuvant has been renowned to improve characteristics of spray solution, effect on atomization, enhancement of retention, change or enhancement of spray deposits and/ or an improved penetration and translocation (Green, 2001; Javaid *et al.,* 2012; Tanveer *et al.,* 2015). Post-emergence herbicides are absorbed through leaf cuticle which consists of waxes and cutin that resist to the absorption of herbicides (Hatterman-Valenti*et al.,* 2011). Alkyl ether sulphate potential to increase post emergence herbicides efficacy as adjuvant have been reported in literature (Javaid *et al.,* 2012).

Use of narrow rows and/or higher population of plants accelerates the canopy establishment rapidly and improves canopy radiation interception, thereby increasing growth and yields of crop (Andrade *et al.,* 2002) and suppresses the growth and competition of weeds (Mashingaidze, 2004; Alford *et al.,* 2004; Ali *et al*., 2016). The early establishment of crop canopy and reduced weeds growth may have no adverse effect on yield of maize (Alford *et al.,* 2004) or result in significant increase in grain yield (Tanveer *et al.,* 2015).Thus, more competitive ability of crop plants due to close canopy may lead to possibility of controlling weeds using low herbicide doses.

Use of herbicide mixtures is strongly preferred over use of individual herbicide due to their broad weed control spectrum, less application cost and potential to delay resistance (Jhala *et al.,* 2013; Abbas *et al.,* 2016b). Keeping in view the above mentioned facts, the present study was designed to identify the effect of row spacing and a new pre-mixed post emergence herbicide (Atrazine + mesotrione + halosulfuran methyl) alone and along with adjuvant on weed control, maize yield and yield attributing components. Use of pre-mixed herbicide at reduced dose will help to minimize the environmental safety concerns and herbicide resistance.

MATERIALS AND METHODS

Field experiments were conducted at Agronomic Research Area, University of Agriculture Faisalabad to study the possibilities of reducing dose of atrazine + mesotrione + halosulfuran methyl through tank mix application of adjuvant and narrow rows during 2014 and 2015 on spring sown maize. The experiment was conducted in a randomized complete block design with factorial arrangement having three replications and a net plot size of 5 m × 3 m. The experiment was comprised of application of nicosulfuran + atrazine + propisochlor @ 555 g a.i. ha^{-1}(75% of label dose) and370 g a.i. ha^{-1}(50% of label dose) alone and in combination with alkyl ether sulphate as adjuvant. The recommended doses of nicosulfuran + atrazine + propisochlor @ 740 g a.i. ha^{-1} and weedy check were also included for comparison.

The maize hybrid DK-919 was sown in 60 cm and 75 cm apart rows on well prepared seedbed in July 2014 & 2015. Fertilizer was applied at 272, 114 and 124 kg NPK ha^{-1}as Urea, DAP and SOP, respectively. Complete dose of phosphorus and potassium and one third of nitrogen was applied as a basal application at sowing and the other two thirds were top dressed in two equal splits after 5 and 7 weeks of maize seed emergence. Maize stalk borer (*Buseola fusca*) was controlled by applying furadan granules in the maize funnel at 4 weeks after emergence. Other agronomic practices were kept optimum during whole period of study. The density and biomass of weeds were recorded by using quadrats of 1 m^2 at random from each plot. Ten cobs were selected from each plot for recording data on number of rows per cob. Two samples of 1000-grain weight each were weighed and average was calculated. Grain yield were recorded on per plot basis and were converted to kg ha^{-1}.

Analysis of variance

Source of variance	Degree of freedom	Weed density	Weed dry wt.	Grains per cob	1000-grain wt.	Grain yield
Replication	2					
Row Spacing	1	4.01^{NS}	0.01^{NS}	202.77**	53.20**	3.23^{NS}
Herbicide	5	7493.57**	2397.94**	83.60**	37.33**	85.83**
Interaction	5	11.09**	2.85*	3.60*	0.67^{NS}	0.17^{NS}
Error	22					
Total	35					

NS = Non-significant, * = Significant, ** = Highly significant

Fisher's analysis of variance technique was used and comparison of treatments were done using least significant difference (LSD) test at P≤ 0.05 (Steel *et al.,* 1997).The year effect was non-significant, therefore data were pooled before statistical analysis.

RESULTS AND DISCUSSION

Total weed density at harvest m^{-2}

Weeds are unwanted as these are crop damaging factor. Weeds reduces crop yield, so with good control of weeds we can increase yield. Weed control treatments and row spacing affected total weed density significantly (Fig. 1). Interactive effect of row spacing and weed control treatments was also significant. The significantly highest weed density (114 m^{-2}) was recorded in weedy check treatment where crop was sown in 75 cm apart rows (W_0S_2) while the lowest (17 m^{-2}) was recorded with atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i. ha^{-1} + alkyl ether sulphate sodium salt @ 396.8 mL ha^{-1} under 60 cm spaced rows (W_4S_1) but was statistically similar with same herbicide treatment under wider spacing (W_4S_2). The total weed density was reduced significantly with reducing herbicide dose at both spacing and addition of adjuvant significantly decreased the weed density of weeds at 50% (W_5) and 75% (W_4) doses under both row spacing. The addition of adjuvant with 75% of labeled dose increased the herbicide efficacy and resulted in statistically similar density to that of labelled dose of herbicide. Similarly, 50% of the recommended dose with adjuvant and 75% of recommended dose without adjuvant resulted in statistically similar weed density at both row spacing. The differences between weed densities at both row spacing were non-significant with all weed control practices except weedy check, atrazine + mesotrione + halosulfuron methyl @ 719.2 g a.i ha^{-1} (W_1) and atrazine + mesotrione + halosulfuron methyl @ 359.6 g a.i ha^{-1} (W_3). Whereas, in weedy check narrow row spacing suppressed weed density while in atrazine + mesotrione + halosulfuronmethyl @ 719.2 g a.i ha^{-1} (W_1) and atrazine + mesotrione + halosulfuron methyl @ 359.6 g a.i ha^{-1} (W_3) treated plots weed density was higher in narrow spacing.

More density of weeds under weedy check might be due to fact that the weed growth was more vigorous in the absence of any weed control treatment and more emergence of weeds (data not given) because no herbicide was applied there. Decrease in density of these weeds with application of herbicide can be attributed to mortality of weeds due to phytotoxic effect of herbicide. These results are in line with those of Javaid and Tanveer (2013) and Tanveer *et al.* (2015). They reported that there were significant difference in weed density of various weed control practices and the weed growth was also negatively affected. The addition of adjuvant resulted in increase of herbicide efficacy that significantly lowered weed density. The lower density of weeds with alkyl ether sulphate at 400 ml ha^{-1} addition can be attributed to greater absorption of herbicide by weeds increasing herbicide phytotoxicity. The outcomes are supported by the findings of Javaid and Tanveer (2013) who reported that use of adjuvants with herbicides increased the weed control efficacy of herbicides.

Total dry weight of weeds at harvest (g m^{-2})

Dry weight of weeds tells us how weed control treatments affected dry matter accumulation of weeds. The data showed that interaction between weed control treatments and narrow row spacing was significant while effect of row spacing alone was observed non-significant (Fig. 2). The more dry weight of weeds (82.73 g m^{-2}) was documented in weedy check sown at 75 cm row spacing (W_0S_2) and was followed by same treatment sown under 60 cm row spacing (W_0S_1). The significantly lowest above ground dry biomass of weeds (9.27 g m^{-2} and 9.66 g m^{-2}) was recorded in treatment where atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i ha^{-1} + alkyl ether sulphate @ 396.8 mL ha^{-1} was applied under both narrow and wider row spacing (W_4S_1 and W_4S_2), respectively. The application of atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i ha^{-1} + alkyl ether sulphate @ 396.8 ml ha^{-1} (W_4) resulted in considerably lower dry weight of weeds compared with atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i ha^{-1} (W_2) alone. The effect of row spacing was not significant under all weed control treatments except the treatment where atrazine + mesotrione + halosulfuron methyl @ 359.6 g a.i ha^{-1} (W_3) was applied. Higher dry weight of weeds in weedy check plot can be attributed to greater density of weeds (Fig. 2) and better growth due to no phototoxic effect of herbicide. Reduced weeds biomass in narrow row maize was due to more competitive ability of maize crop and early canopy closure. Decrease in weed biomass with reduced row spacing in maize has also been reported by Fanadzo *et al.* (2010) and Ali *et al.* (2016). Parwada *et al.* (2011) reported that reduced dosage of herbicide with tank mixed adjuvant can control weeds effectively. The addition of adjuvant resulted in significantly lower weed biomass than use of herbicide without adjuvant. The lower density of weeds with addition can be attributed to greater absorption of herbicide by weeds. Moreover, the use of adjuvant improves herbicide treatments efficacy and can compensate for reduced herbicide dose (Javaid *et al.*, 2012; Javaid and Tanveer, 2013).

Number of grains per cob

The herbicide treatments, row spacing and their interactive effect significantly influenced grains per cob. The highest grains count per cob (613.77) was recorded where atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i. ha^{-1} + alkyl ether sulphate sodium salt @ 396.8 mL ha^{-1} was applied which was sown at 75 cm rows apart (W_4S_2). However, the lowest grains count per cob (470.30) were achieved in plots where no treatment was applied (W_0S_1). The highest grains count per cob (613.77) were achieved in atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i. ha^{-1} + alkyl ether sulphate sodium salt @ 396.8 mL ha^{-1} (W_4S_2) treated plots that was statistically at par with the treatment where recommended dose of that herbicide (W_1S_2) was applied i.e. (600.60). Decrease in herbicide dose caused significant reduction in the grain count per cob. Number of grains per cobs was positively affected with addition of adjuvant. This may be due to good crop growth because of less weed competition. Whereas, grain count per cob at recommended field rate of herbicide without adjuvant showed similar results as 75% of the field rate with adjuvant. Although more weed density and biomass was recorded in wider row spacing yet the number of grains per cob was more in this treatment.

The more number of grains in herbicide treated plots could be because of better weed control which enhanced the growth of crop plants due to reduced competition. Tanveer *et al.* (2015) have also reported decrease in grains per cob under weedy check compared with weed control treatments. The interactive effect of herbicide doses and row spacing was significant. The greater number of grains per cob might be due to decreased interplant competition at wider spacing. The increase in grains per cob in wider rows has been suggested as the decreased result of intra plant competition for resources (Shapiro and Wortmann, 2006).

Addition of adjuvant significantly enhanced the number of grains. This increase in number of grains can be attributed to decreased weed crop competition due to the better weed control. These findings are strongly supported by those of Nalewaja *et al*. (2008) and Tanveer *et al.* (2015) who concluded that all weed control treatments using herbicide with adjuvant significantly increase the number of grain rows and number of grains per cob.

1000-grain weight (g)

Comparison of data (Fig. 4) showed that the weed control treatments and row spacing affect 1000-grain weight considerably while their interaction did not. The highest 1000-grain weight (268.17 g) was recorded in plots where atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i ha^{-1} + alkyl ether sulphate @ 396.8 mL ha^{-1} (W_4) was applied and was statistically similar with recommended dose of herbicidealone (W_1). It was followed by atrazine + mesotrione + halosulfuron methyl @ 359.6 g a.i ha^{-1} + alkyl ether sulphate @ 396.8 mL ha^{-1} (W_5) which was statistically similar with atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i ha^{-1} (W_2). Significantly lowest

1000-grain weight (238.27 g) was recorded in weedy check treatment (W_0). The interactive effect of herbicide treatments and row spacing was statistically non-significant. More 1000-grain weight in herbicidal treatments than weedy check was the result of improved growth of maize plants due to less weed competition. As herbicide application caused significant reduction in density and dry biomass of weeds. These results are supported by the findings of Nadeem *et al.* (2008) who reported more 1000-grain weight in herbicides treated plots than untreated control. These results are in close agreement with Tahir *et al*. (2011) and Tanveer *et al.* (2015) who found that use of herbicides to control weed resulted in increased 1000-grain weight of maize. There is a significant difference between row spacing as higher 1000-grain weight was observed in case of maize sown under 75 cm apart as compared to maize sown under narrow row spacing. This might be due to lower interplant competition with wider row spacing and more availability of resources for plants. The results are contradictory to those of Shapiro and Wortmann (2006), who found that narrow row spacing resulted in a little benefit in increasing grain yield. These contradictory results might be due to differences in weed flora and genetic makeup of the crop plants.

Grain yield (t ha^{-1})

All the herbicidal treatments caused significant increase in grain yield of maize as compared with weedy check (Fig. 5) while row spacing did not affect grain yield significantly. Atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i. ha^{-1} + alkyl ether sulphate sodium salt @ 396.8 mL ha^{-1} (W_4) gave highest grain yield (8.18 t ha^{-1}) and was statistically similar with atrazine + mesotrione + halosulfuron methyl @ 719.2 g a.i ha^{-1} (W_1). It was followed by the treatment where atrazine + mesotrione + halosulfuron methyl @ 539.4 g a.i. ha^{-1} (W_2) was applied (7.12 t ha^{-1}) which was statistically at par with atrazine + mesotrione + halosulfuron methyl @ 359.6 g a.i ha^{-1} + alkyl ether sulphate sodium salt @ 396.8 mL ha^{-1} (W_5). The grain yield decreased significantly with each decreased herbicide dose. However, addition of adjuvant resulted in significantly higher grain yield compared with herbicide alone with same dose. The use of adjuvant with 75% of herbicide labeled dose (W_4) resulted in statistically similar grain yield with that of labelled dose of herbicide (W_1). Similarly, addition of adjuvant with 50% of labelled dose (W_5) resulted in statistically similar grain yield to that of 75% of labelled dose without adjuvant (W_2). The significantly lowest grain yield (5.63 t ha^{-1}) was recorded in weedy check plots (W_0).

The higher grain yield with herbicide treatments over weedy check can be attributed to more number of grains per coband 1000-grain weight. The efficiency of chemicals with adjuvant and other weed control practices in increasing grain yield had also been revealed by Tahir *et al*. (2011), Khan *et al*. (2002) and Khan and Haq (2004),who reported that when herbicides were used, the maize yield was increased significantly as compared with an unweeded control. Tahir *et al.* (2011) and Tanveer *et al*. (2015) also reported that the addition of adjuvants enabled the reduction in herbicide concentration in maize without affecting its yield. The effect of row spacing and interaction between row spacing and weed control methods was non-significant. Although the number of grains per cob and grain weight were increased with wider row spacing but due to lower plant population at this spacing the grain yield per unit area was found non-significant. With reduced row spacing no effect on yield might be due to that with narrowing row spacing 1000-grain weight reduced.

CONCLUSION

Expected results were successfully achieved with the conclusion that use of alkyl ether sulphate as adjuvant and narrow spacing caused significant reduction in the dose of herbicide without compromising weed control efficacy. Based on present results it is suggested that the dose of atrazine + mesotrione + halosulfuron methyl can be reduced up to 25% (75% of recommended) by addition of alkyl ether sulphate as adjuvant or growing maize at 60 cm row spacing.

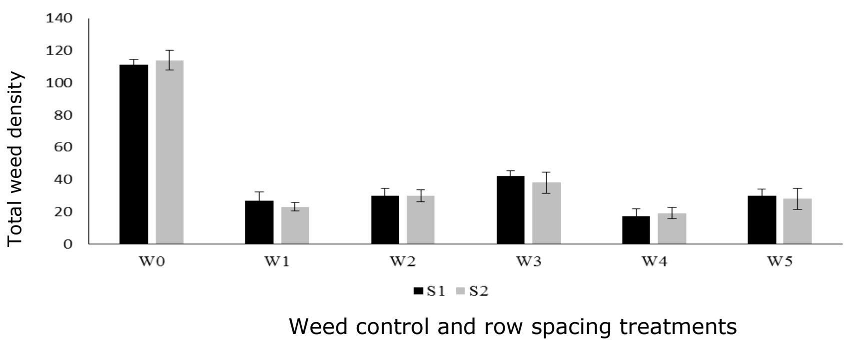


Figure 1. Total weed density (m^2) at harvest as influenced by different weed control and row spacing treatments in maize.

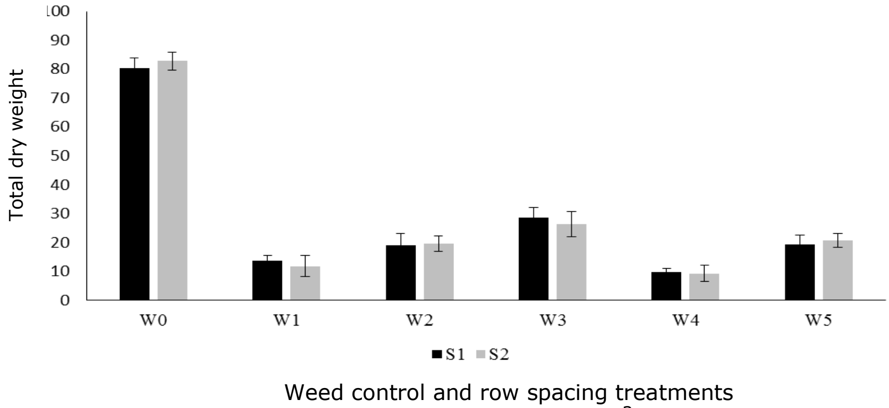


Figure 2. Total dry weight of weeds (g m^{-2}) at harvest as influenced by different weed control treatments and reduced row spacing in maize

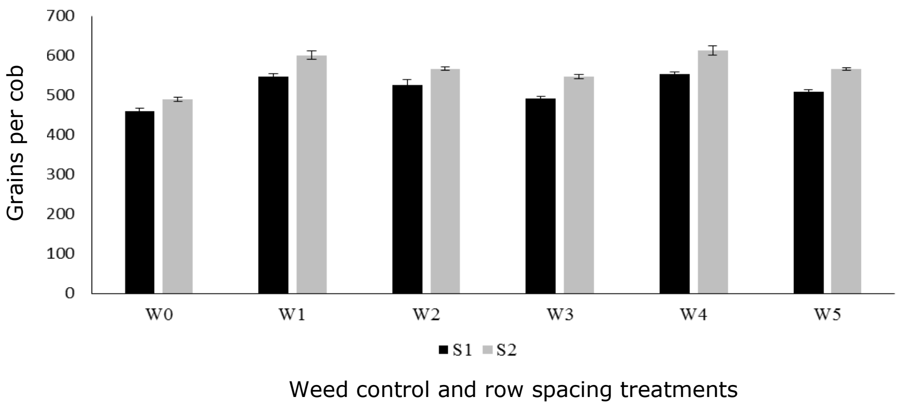


Figure 3. Number of grains per cob as influenced by different weed control treatments and reduced row spacing in maize

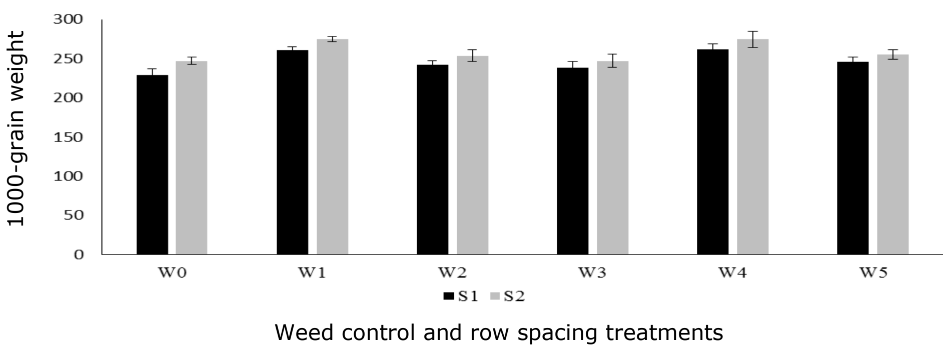
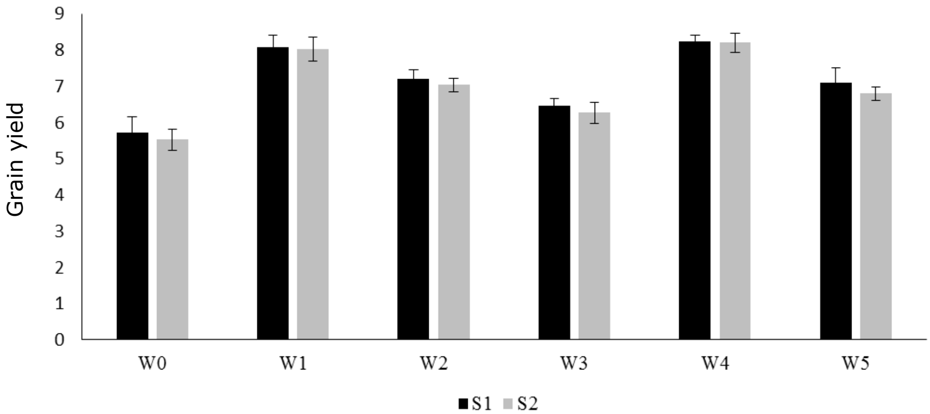


Figure 4. 1000-grain weight of maize as influenced by different weed control treatments and reduced row spacing



Weed control and row spacing treatments

Figure 5. Grain yield of maize as influenced by different weed control treatments and reduced row spacing

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