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Reduced doses of total herbicide used together with plant density for weed management in wheat (*Triticum durum* L.) fields

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Abstract

Reduction in herbicide usage without compromising yields can lead to less environmental harm and lower production costs. We evaluated the effects of both the plant population and reduced doses of sulfosulfuron plus metsulfuron-methyl on the weed infestation and crop performance of wheat. Results experiments revealed that a fairly acceptable level of weed suppression in wheat fields was achieved with lower doses of sulfosulfuron plus metsulfuron-methyl (30 g a.i. ha^{-1}) in combination with plant density of 500 plant m^{-2} that were comparable to results with its label dose. Increased seeding rate was able to increased grain yield and number spike m^{-2}. However, 1000-grain weight decreased with increasing seeding rate. The results suggested that weeds can be controlled in wheat, for a higher yield, when a reduced herbicide dose is used in combination with increasing seeding rate.

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Introduction

Problems such as high weed infestation, delayed sowing, poor nutrition and drought are the major reasons which lower wheat yield and threatening food security (Hussain *et al.,* 2010; Jabran *et al.,* 2011). Weeds left unmanaged, cause massive yield losses in wheat and other field crops (Jabran *et al.,* 2008, 2010; Razzaq *et al.* 2010; Akbar *et al.,* 2011).Chemical weed control is a very effective method for suppressing weeds, and herbicides proffer a substantial boost in crop productivity through efficient weed control (Santos, 2009). Indiscriminate use of herbicide may lead to crop injury, human and animal health concerns, soil and water pollution and herbicide resistance in weeds (Jabran *et al.,* 2008; Farooq *et al.,* 2011). The efficacy of any herbicide depends predominately on the dose used (Steckel *et al.*, 1997) and in many instances the same is also decisive for its selectivity. Registered herbicide doses are set to achieve upper limits of weed control under varying compositions, densities, weed growth stages and environmental conditions, and there may be an overestimation of the dose required to get adequate control (Zhang *et al.*, 2000). To ensure satisfactory weed control, even under unfavorable regimes of crop production factors, manufacturers often recommended higher than necessary doses of an herbicide. However, it is not always necessarily to apply full herbicide dose (Talgre *et al.*, 2008) and there can flexibility regarding herbicide rates depending on the weed spectrum, densities, their growth stage and environmental conditions of the site. Moreover, modern weed science also emphasizes following an ecological approach based on keeping weed populations below threshold levels rather than eradicating them (Barroso *et al.*, 2009). As a general principle, a lower dose of herbicide may kill most of the target weeds under favorable conditions. Under less favorable conditions, a higher dose will be required, and under unfavorable conditions even the highest doses of herbicide may still give unsatisfactory results (Medd *et al.*, 2001). On the other hand, Crop density significantly influences the incidence of weeds due to their competition for resources. As a consequence, the contribution of each individual plant to the overall may not be optimized. Indeed, higher plant densities result in reduced tiller and grain numbers per plant even though the overall yield per area may remain the same (Lemerle *et al.*, 1996).Thus, optimal plant density and weed infestation need to be established to reduce crop-weed competition. The aim of this study was to investigate the effect of seeding density and reduced dose of sulfosulfuron plus metsulfuron-methyl on the yield performance of wheat.

Materials and methods

Design of Field Experiment

Field experiments were conducted at the Shoushtar Branch, Islamic Azad University, Iran (32 º 3´ N, 48º 50´ E). during winters of 2012-2013 to evaluate the weed suppressive activity sulfosulfuron plus metsulfuron-methyl at 20, 30 and 40 g a.i. ha^{-1}, applied at reduced rates and wheat density at 300, 400, 500 and 600 plant per m^2. Experiments were laid out in a randomized complete block design (RCBD) with a factorial arrangement and four replicates. The net plot size was 6 m × 2. m. The soil was a clay loam texture, **p**H of 7.4 and 0.6 % organic matter content. The 30-yr average annual rainfall is 321.4 mm, average annual air temperature is minimum and maximum 9.5 °C and 46.3 °C, respectively. Wheat cv. Behrang was planted in the first fortnight of November. Seedbed preparation consisted of moldboard plowing, disking and leveling. A basal fertilizer dose of 125 kg N, 75 kg P_2O_5, and 60 kg K_2O ha^{-1} was applied in the form of urea (46% N), diammonium phosphate (18% N; 46% P_2O_5) and sulfate of potash (50% K_2O). The whole P and K and half of N were applied at sowing. The remaining half of N was top dressed with the second irrigation at the booting stage. Besides soaking irrigation, four irrigations were applied to produce the wheat crop.

Statistical Analyses

All data were subjected to analysis of variance using SAS statistical software (SAS, Institute, 2000), and means were separated using protected LSD at P=0.05.

Results and discussion

Effect of seed rate and reduced doses on the density, biomass accumulation and seed formation of malva

As the crop population brings competition for limited resources with the weeds, we tested different seeding rates to increase crop plant density as a measure to control weeds. The weed population was significantly affected by seed rate ($p < 0.05$; Table 2): The highest weed density (m^{-2}) was observed in the area with the lowest seed rate (i.e. 300 plant m^{-2}). The lowest weed density was recorded in the area with the seed rate of 600 plant m^{-2}. There were no significant difference in weed densities between areas with a seed rate of 500 and 600 plant m^{-2}. In general, however, there was an inverse relationship between a decreasing weed density ($p < 0.01$) and an increasing seed rate. The increased seed rate resulted in a higher crop plant population providing less space for weeds to grow and offering much higher competition for light, nutrient and other growth factors. These factors collectively resulted in lower weed density. Increasing seed rate of wheat significantly decreased ($p < 0.01$) weed dry weight. The seeding rate also has a profound effect on the weed dry weight in wheat. The highest weed dry weight was recorded in the seed rate of 300 plant m^{-2} and the lowest was found in 600 plant m^{-2}. There are several reasons why there was a lower density of weed infestation in areas that had a higher seed rate. Guillermo *et al.* (2009) showed that areas with higher plant densities might have a competitive advantage over weeds due to fast canopy development. A higher seeding rate may keep the weed flora under check through a smothering effect (Mahajan *et al.*, 2010). Mohler (1996) revealed that a higher seeding rate may provide a competitive advantage to crop over weeds because crop plants will absorb limited resources at a faster rate. However, an increased seeding rate may not always increase the weed competitiveness of a crop, and greater intra-crop competition may arise. This may lead to negative effects on crop production, especially under stressful environmental conditions (Krikland *et al.*, 2000). Therefore, an optimal seed rate, along with some weed control, is frequently practiced. For instance, Khaliq *et al.* (2012) showed that higher seeding density and herbicide tank mixture furnished effective weed control in direct seeded rice. Different doses of sulfosulfuron plus metsulfuron-methyl demonstrated a significant effect on total weed density (Table 1), and the difference was more pronounced at 40 g a.i. ha^{-1}. Reduced rates of sulfosulfuron plus metsulfuron-methyl were relatively more inhibitory to broad-leaved species as against grasses. Application of sulfosulfuron plus metsulfuron at various doses was equally ($P \leq 0.01$) effective in suppressing DM and seed formation of malva (Table 2). Increasing seeding rates was led to a significant ($P \leq 0.01$) reduction in malva dry weight, as the maximum and minimum of malva biomass recorded in 300 and 600 plant m^{-2} respectively, (Table 2). A result of some study showed that increasing crop density was reduces biomass and seed production in wild oat (Roberts *et al.*, 2001; Scurson and Satorre, 2005; Lemerle *et al.*, 2004; Olsen *et al.*, 2012). These results suggest that the magnitude of suppression achieved in combination of higher seed rate (500 and 600 plant m^{-2}) when the application volume of sulfosulfuron plus metsulfuron was reduced.

Table 1. Mean effects of herbicide doses and plant density on reduction percentage of malva.

Doses of herbicide	No. of malva before treatment	No. of malva after treatment	% Reduction
20	39.9	8.56	78.33c
30	38.75	6.56	83.69b
40	44.43	5.5	88.94a
Plant density			
300	50.42	11.28	77.01c
400	47.25	7.87	83.05b
500	39.75	3	92.49a
600	30.25	2.12	93.96a

Table 2. Interaction effects of herbicide doses and plant density on dry matter accumulation and seed formation of malva.

	Dry weight (g m $^{-2}$)				Seed m $^{-2}$			
Treatment	300	400	500	600	300	400	500	600
Weedy	920a	810b	780c	750d	1280a	1280a	1240b	1240b
20	220e	190f	185f	160gh	980c	980c	400g	350h
30	170g	150ij	140ij	128l	800d	800d	280i	220j
40	160hi	135kl	130l	125l	680e	620f	290i	230j

Effect of seed rate on yield related to characteristics of wheat

A number of variables were significantly influenced ($p < 0.01$) by seed rate and reduced rates of sulfosulfuron plus metsulfuron-methyl: productive tiller m $^{-2}$, spikelet spike $^{-1}$, grains spike $^{-1}$, 1000 grain weight, grain yield, biological yield and harvest index, however interactions were not significant (Table3).

Table 3. Interaction effects of herbicide doses and plant density on yield and yield components of wheat.

H. treatments	Productive tillers m $^{-2}$	Spikelet spike $^{-1}$	Grains spike $^{-1}$	1000-grain weight	Grain yield m $^{-2}$	Biological Yield m $^{-2}$	Harvest index
weeding	499.4b	19.63a	38b	26.37a	458.2a	1590a	29.24b
No weeding	354.7d	5.12e	19.33 e	15.19d	336.3d	1281e	26.63e
20	474.7c	8.75d	20.16 d	19.12c	386.3c	1401d	28.01d
30	514.7a	12.75c	28.19 c	23.6b	414.3b	1489c	29.8a
40	520.3a	16.8b	40.69a	24.15b	426.3b	1550b	28.54c
P. density							
300	329.4d	16.7a	25.8c	25.6a	391.5d	959.3d	30.26a
400	408.1c	13.2b	26.95c	23.23b	345.8c	1162c	29.64a
500	503.4b	10.7c	36.8b	22.76c	519.3a	1861b	27.86b
600	650a	9.75d	38.65a	15.46d	486.3b	1866a	26.01c

The number of productive tillers per meter decreased with the increase of the plant density from 300 plant m $^{-2}$, to 600 plant m $^{-2}$. The highest number of productive tiller per meter (650) was recorded at the 600 plant m $^{-2}$ seed density. The lowest number of tillers per meter was recorded at the 300 plant m $^{-2}$ seed density. The highest number of spikelet spike $^{-1}$ was produced at a lower seed density (300 plant m $^{-2}$). The highest number of grains per spike and biological yield was observed in the seed rate of 600 plant m $^{-2}$, illustrating an increasing trend with rising seed rate. On the other hand, the highest 1000 grain weight was found in the seed rate of 300 plant m $^{-2}$, while the lowest values was in the seed rate of 600 plant m $^{-2}$. The harvest index was the highest for the 300 plant m $^{-2}$seed rate followed by the 400, 500 and 600 plant m $^{-2}$ seed rate. This contributed to the maximum yield, which was due to a more dense plant population with moderately higher fertile flowers than that of lower plant population with a higher fruit set. There is a relationship between seed rate and yield related characteristics and our results closely resemble numerous extant research findings (Zhao *et al.*, 2007; Lin *et al.*, 2009; Mahajan *et al.*, 2010). Increased wheat grain yield by increasing the amount of seeding rate reflects the increasing competitiveness of wheat in competition with malva and spike numbers per square meter. Increased seeding rate over of 500 plant m $^{-2}$ was reduced wheat grain yield. Under dense populations due to reduced light interception and CO_2 accumulation, the overall yield may be limited. Baloch *et al.* (2002) revealed that under increased plant density, intra-specific competition for light and nutrient leads to a reduction in grain yield. Mahajan *et al.* (2010) showed that with increased rice plant density, beyond the optimal level, might lead to high dilution effect resulting in lower yield. On the other hand, lower yield at less-than-optimal densities is probably due to the inability to intercept maximum available light due to poor stand establishment. In fact, intra-specific competition due to different seeding densities may vary in their intensity and compensatory growth of individual plants, when grown at lower densities, results in similar grain yield over a broad range of densities (Bond *et al.*, 2005).

In conclusion, the seed rate and weed density significantly influenced the plant growth and yield parameter. These results provide a reasonable base for suggesting that combined plant population of 500 plant m^{-2} used with reduced rates of sulfosulfuron plus metsulfuron-methyl (30 g a.i. ha^{-1}) is economical and will raise net benefits on one hand, and increase environmental safety by reducing reliance on synthetic herbicides on other hand.

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