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Effect of nitrogen fertilizer and herbicides on weed control and wheat grain yield under subtropical conditions

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Abstract

In order to study the interaction effect of nitrogen (N) rates and herbicides (H) on weed control and wheat grain yield, this experiment was carried out in South-west of Iran which has subtropical climate, mild winters, and hot, dry summers. The experiment was a factorial using randomized complete block design with three replications. Four rates of N fertilizer (urea) (50, 100, 150, 200 $kgNha^{-1}$) and three herbicide treatments including Apirus (Sulfosulfuron), Tapik (Clodinafop-Propargyl) + Granestar (Tribenuron-Methyl), Tapik + Duplosan Super (Dichlorprop-P + MCPA + Mecoprop-P) along with unweeded control treatment were examined. The increase of N rates increased the density of narrow-leaf weeds and reduced herbicides control efficiency. Herbicide susceptibility of weed species was influenced by N. The highest weed control efficiency was recorded in Apirus which was significantly different from the other two herbicides. The interaction effect of N×H on grain yield was significant ($P<0.01$). The highest and the lowest wheat grain yield were respectively recorded in Apirus and combination of Tapik + Granestar. The use of Apirus, Tapik + Granestar and Tapik + Duplosan Super increased the wheat grain yield 43%, 35%, and 25%, respectively in relation to unweeded control. Higher grain yield in Apirus treatment was due to further control of the weeds (93%). Generally, the results indicated that Apirus herbicide was more efficient than others in controlling narrow and broad-leaf weeds. Unlike other herbicides treatments, Apirus had likely similar efficiency in all N rates while in other herbicide treatments the increase of rates of N and the weed biomass decreased the weed control efficiency.

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Introduction

Wheat (*Triticum aestivum* L.) is the most important crop among food cereals. There are a good number of factors responsible for low yield among which one major cause is weed infestation. Weeds compete with wheat for nutrients, water, and light therefore reducing crop yield and grain quality. Control of weeds is a basic requirement and major component of management in most crop production systems. Increasing crop competitiveness is an important component of integrated weed management. In this regard, it is necessary to know the weeds response to the soil fertility for developing fertilizing methods as the components of integrated management programs (Moradi-Talavat *et al.*, 2010). Fertilizing crops is associated with the weeds access to nutrients. Since crops and weeds have almost similar needs, soil fertility affects their competition. The nitrogen (N) fertilizer application may influence germination, emergence, and competitiveness of weeds (Blacshaw, 2004). Different selection pressures have led to distinct physiological traits pertaining to nutrient acquisition and growth, which influences the competitive balance between crops and weeds (Ditomaso, 1995). Results of some researches indicated that by using more nitrogen the weeds competitiveness enhanced in relation to crops. (Cathacart and Swanton, 2004; Delaney & Van-Aker, 2005). The reason is higher efficiency of the weeds in using related resources. If the application of high levels of fertilizers stimulates the growth of weeds more than the growth of crops, it will exacerbate weed interference effects (Barker *et al.*, 2006; Salas *et al.*, 1997).

Although the use of herbicides is necessary to achieve crops optimum economical yield, these compounds are also considered as pollutants of agricultural ecosystems. In a proper combination, the best result is achieved when the herbicides' efficiency increases in combined mode while the crop is not damaged. However, there might be some problems in relation to such combinations such as the residual effects of herbicides after crop spraying or crop burning after applying herbicides since their mixture is not made by the manufacturers. Moreover, it is possible that mixture of two herbicides will have negative, reducing effects or will not be different from non-mixture (Rashed & Vafabakhsh, 2009). Therefore, producing new herbicides and directing researches towards the minimum use of chemicals and the use of more effective herbicides in lower doses and also the periodic use of herbicides in order to decrease herbicide- resistant weed biotypes and to have fewer negative effects on the environment are always emphasized. Therefore, in recent years some dual-purpose chemicals have been introduced under the title of herbicides which are able to control different kinds of narrow and broad-leaf weeds by spraying once and in this case, there is no need to mix the herbicides.

At present limited selective herbicides are used in the wheat fields of Iran. Recently a sulfonylurea herbicide named sulfosulfuron (Apirus) has been widely applied as a dual-purpose herbicide in Iran to control narrow and broad-leaf weeds of wheat fields which has been acceptable according to the reports (Zand *et al.*, 2008). This herbicide prevents the activity of Acetolactate Synthase enzyme which is responsible for producing three essential amino acids in crops named Leucine, Isoleucine and Valine.

Investigation of N fertilization and herbicides might be useful in managing weeds in wheat crop. Fertilization is known to influence weed community structure and crop competitive ability against weeds. Also, the application of herbicides could have different efficiency under different rates of nitrogen (Sonderskov *et al.*, 2012). Jarwar *et al.* (1999) observed that chemical weed control method was more effective when integrated with cultural methods of weed control. Thus, keeping in mind the usefulness of herbicides and N fertilization, this present trial was undertaken to find out the most effective herbicides for weed control in wheat, to find out the optimum N application rate for promoting growth of crop plants against the weeds and better integration of herbicides and N fertilizer for achieving maximum yield.

Materials and methods

Study site

This research was conducted in south west Iran at longitude 48°22´ east and at latitude 32°29´ north, with average rainfall of 355mm per year. The experimental site has sub-tropical climate with hot summers, moderate winters and 150m height above the sea level. The soil was clay loam in texture, pH 6.7 with low organic carbon (less than 1%), moderate phosphorus (8.1 ppm) and high potassium (240 ppm) status.

Experimental design and crop managements

It was a factorial experiment using randomized complete block design with three replications. The first factor of the experiment included four levels of nitrogen fertilizer (urea) (50, 100, 150, 200 kgNha^{-1}). The second factor was herbicide treatments included Tapik + Granestar (1/2 l.ha^{-1} and + 20 g.ha^{-1}), Tapik + Duplosan Super (1/2 + 1 l.ha^{-1}), Apirus (25 g.ha^{-1}) and unweeded control treatment (without herbicide application).

Each experimental plot contained five cultivation lines each one as long as 3m. According to the results of soil experiment, Triple Super Phosphate was used as much as 150 kgha^{-1} before cultivation. After preparing the farmland, Chamran wheat seed was planted linearly on 22nd Nov. At all application rates, half was applied before sowing and the remaining N was applied as a top dressing at the beginning of wheat tillering corresponding to stage 21 of Zadoks scale. 100 kgha^{-1} Phosphorus from Triple Super Phosphate was distributed among the plots during the final leveling process.

In this experiment backpack sprayer with flat fan nozzles was used. Spraying operation was done with carrier volume of 300 L.ha^{-1} and 200 kPa. In order to study the weeds traits, 0.5×0.5 quadrate was used. When sampling, the number of weeds including narrow leaves and broad leaves was counted and then got dry in the oven and weighed. Narrow and broadleaves weed composition of the experimental fields is presented in table 1.

In order to evaluating the efficiency of weed control, the equation (1) was used:

$$WCE = \frac{A - B}{B} \times 100 \quad (1)$$

In this equation, *WCE* is the weed control efficiency (reduction of weed biomass in percent), A is weed density in control plot and B is the number of weeds in treatment plots.

Grain yield and yield components analysis

In order to determine the wheat grain yield and its components, harvest was done after eliminating half a meter of the beginning and end of each plot of third and fourth lines in an area equal to 1.2 m^2. After threshing, the grains were separated from the chaff and after weighing, the grain yield was calculated. In order to evaluate the wheat grain yield components all spikes of two half-meter lines were picked up and the number of spikes per square meter, spikelet per spike, and grains per spikelet were counted. Harvest index (HI) was calculated by equation 2:

$$HI = \left[\frac{GY}{BY}\right] \times 100 \quad (2)$$

In this equation, GY and BY are grain yield and biological yield respectively. The weight of 1000-grain was obtained in gram by counting four samples of 250 grains.

Statistical analysis

Data analysis of variance was done through SAS9.1 statistical program and the means were compared by Duncan's multiple range tests at 5% probability level.

Results and discussion

Weed Control

Results indicated that increasing N rates enhanced the density of narrow leaf weeds (Table 2). The difference between broad-leaf weeds with different rates of N was not significant. It has been reported that the increase of N dose leads to the increase of the number and biomass of some weeds (Blacshaw *et al.*, 2003; Khan *et al.*, 2012). Research shows that narrow and broad-leaf weeds have different reactions to N fertilizer (Jornsgard *et al.*, 1996 and Hussein *et* *al.,* 2007) and the kind and the dose of N application might affect the structure of the weeds population (Cathcart & Swanton, 2004a). Among the herbicide treatments, Apirus and the mixture of Tapik + Duplosan Super had the highest and the lowest efficiency of controlling narrow-leaf weeds. The difference between Tapik + Granestar mixture and Apirus was not significant in controlling narrow-leaf weeds. Moradi-Talavat *et al.* (2010) concluded that Tapik herbicide controlled the narrow-leaf weed of Wild oats significantly. The efficiency of Apirus herbicide in terms of controlling narrow-leaf weeds such as Phalaris has been reported to be about 20-60% (Zand *et al.*, 2008).

Table 1. Narrow and broadleaves weed composition of the experimental fields.

Name	Family	Genus	Species
Narrow leaves			
Ryegrass	poaceae	*lolium*	*temulentum*
Wild oat	poaceae	*Avena*	*fatua*
Canary grass	poaceae	*Phalaris*	*minor*
green foxtail	poaceae	*Staria*	*viridis*
Broad leaves			
Wild mustard	Brassicaceae	*Sinapise*	*arvensis*
Common mallow	Malvaceae	*Malva*	*rotundifolia*
Curly dock	Polygonaceae	*Rumex*	*crispus*
Tumble mustard	Brassicaceae	*Sisymbrium*	*alttissimum*

The reaction of broad-leaf weeds to herbicide treatments was different (Table 2). The difference between Apirus and Tapik + Duplosan Super was not significant in controlling broad-leaf weeds. The lowest weed control efficiency was related to the mixture of Tapik + Granestar. Generally, the highest efficiency of controlling narrow-leaf and broad-leaf weeds was observed in Apirus herbicide which was significantly different from the other herbicides. Although in some researches it has been reported that the mixture of Acetolactate Synthase inhibiting herbicides such as Tapik and hormonal herbicides such as Duplosan Super might have antagonistic effects, the research on the mixture of Tapik and Duplosan Duper is very limited. Duplosan Super is a mixed herbicide which is made of three components: Mecoprop-P, Dichlorprop-P, and MCPA. All components of this herbicide are hormonal ones and are absorbed by the leaves and green parts of the crops and they spread throughout the crops very quickly and disturb their growth balance and impair their respiration. Like other hormonal herbicides the apparent hormone-like effects of this herbicide include plant epinasty. Driver *et al.* (1999) reported that this herbicide can be used as mixed with wheat broad-leaf herbicides such as 24D and its efficiency is more than dual-purpose herbicides. However, the results showed that the mixture of these two herbicides has a higher efficiency than the conventional mixture of Tapik and Granestar (Table 2).

Table 2. The number of narrow and broad-leaf weeds and weed control efficiency of herbicides at different N rates.

Treatments	Narrow leaves (plant .m^{-2})			Broad leaves (plant .m^{-2})			Total (plant .m^{-2})		CE (%)
	Before App.	After App.	CE (%)	Before App.	After App.	CE (%)	Before App.	After App.	
N (kg ha^{-1})									
50	7.5c	0.66b	88.6a	4.4a	0.44a	87.5a	12b	1.1b	90.1a
100	8.6bc	1.33ab	84.7a	5.0a	0.66a	84.8a	14b	2.0a	85.0a
150	10.4ab	2.11ab	78.7a	5.0a	0.88a	78.5a	15ab	3.0a	80.0a
200	12.4a	2.22a	82.1a	5.0a	1.00a	77.0a	17a	3.2a	81.3a
Herbicides									
Tapik+Granestar	10.0a	2.00a	80.0ab	4.5a	1.4a	67.6b	14a	3.4a	77.9b
Tapik+Duplosan Super	9.2a	1.83a	78.5b	4.2a	0.6b	82.0ab	13a	2.5ab	80.4b
Apirus	10.0a	0.91a	91.3a	0.5b	0.1c	96.7a	15a	1.0b	93.4a

In each column, means which have similar letters do not have significant difference based on Duncan's multiple-range test at 5% probability level.

The increase of N decreased the weed control efficiency (Table 3). It seems like that the reason of this reaction was the increase of density and biomass of the weeds at higher rates of nitrogen. The highest and the lowest means of herbicide control were respectively observed in fertilizers with 50 and 200 kgNha^{-1}. Zare *et al.* (2008) reported that more doses of herbicides are required to control weeds in high levels of nitrogen. By studying the effect of some herbicides on controlling narrow-leaf and broad-leaf weeds, Cathcart & Swanton (2004b) concluded that the weeds susceptibility and reaction to herbicides is different at different N levels.

Table 3. Control efficiency (%) of herbicides at different rates of N fertilizer.

Herbicides	N (kg ha^{-1})				Mean
	50	100	150	200	
Tapik+Granestar	88.9	75.9	73.8	73.0	77.9
Tapik+Duplosan Super	83.3	84.4	83.8	80.0	80.4
Apirus	98.1	94.8	89.7	90.7	93.4
Mean	90.1	85.0	81.0	80.3	

The investigation of changes trend of weed control efficiency in herbicide treatments with different levels of nitrogen fertilizer showed that Apirus herbicide had the highest efficiency at different nitrogen levels while two other herbicide treatments had higher slope of changes in terms of reducing control efficiency at higher nitrogen levels (Fig. 1). In other words, at all rates of N treatments, Apirus had more control efficiency than the other treatments.

Wheat Grain Yield and Yield Components

The interactive effect of N×H on grain yield, biological yield, and the traits related to the number of grains was significant (Table 4). All the traits which were studied in the experiment were significantly affected by H treatments (P<1%). The increase of N rates up to 200 kgha^{-1} increased the wheat grain yield but the difference between this treatment and that of 150 kgNha^{-1} was not significant (Table 5). Higher grain yield in 150 and 200 kgNha^{-1} treatments was due to the increase of fertile spikes and the number of grains per spike. The results were consistent with similar results by Modhej *et al.* (2008) and Modhej *et al.* (2012). The wheat biological yield increased in response to nitrogen fertilizer, but the harvest index was not affected.

Table 4. Analysis of variance results of wheat grain yield and yield components in studied treatments.

S.O.V	df.	S.m^{-2}	Sp.S^{-1}	G.S^{-1}	TGW	GY	BY	HI
Rep.	2	283.6	1.38	5.15	8.31	833	15158	22.96
Nitrogen (N)	3	23839.4**	8.89ns	58.47**	83.0ns	134890**	605193**	44.51ns
Herbicides (H)	3	15954.0**	66.56**	251.26**	26.6**	174434**	643360**	91.40**
N×H	9	1301.1*	0.47**	15.18**	0.7ns	6940**	36872**	31.17ns
Error	30	643.7	0.66	5.62	1.6	1343	9245	22.32

** and *: significant at 1% and 5% probability level, respectively. ns: not significant.

Weed interference reduced wheat grain yield. The highest and the lowest grain yield belonged to Apirus and the mixture of Tapik + Granestar respectively (Table 5). The grain yield difference between Apirus and Tapik + Duplosan Super was not significant. The use of herbicides Apirus, Tapik + Duplosan Super, and Tapik + Granestar increased the wheat grain yield 43, 35, and 25% respectively in relation to unweeded control. The high grain yield in Apirus herbicide was due to further control of the weeds (93%). Apirus consumption increased the number of spikes, the number of grains per spike and the grain weight significantly by means of controlling the weeds. The resultant increase of these traits led to the increase of grain yield. The highest grain yield belonged to Apirus with 200 kgNha-1 whose difference with the consumption of Apirus with 150 kgNha-1 was not significant (Table 6).

The number of spikes per square meter was significantly more than that of the other two herbicide components and the plot without weed control. Apirus consumption increased the number of spikes 19.5%. The number of grains per spike was more in Apirus than the other treatments. The difference between the mixture of Tapik+Duplosan Super+Granestar and treatment without control was not significant in terms of the number of grains per spike (Table 5).

Table 5. Comparison of the means of wheat grain yield and yield components in studied treatments.

Treatments	S.m-2	Sp.S-1	G.Sp-1	TGW (g)	GY (g.m-2)	BY (g.m-2)	HI (%)
N (kg ha-1)							
50	301b	13a	22b	44a	382c	856c	44a
100	357a	14a	26ab	45a	472bc	1039bc	45a
150	384a	15a	28a	45a	596ab	1234ab	47a
200	404a	15a	29a	45a	608a	1370a	44a
Herbicides							
Tapik+Granestar	340b	13b	26b	46ab	484b	1049b	46a
Tapik+Duplosan Super	359b	16a	25b	45bc	564b	1166ab	18a
Apirus	413a	17a	33a	47a	648a	1418a	47a
Control	333b	12b	22b	43c	363c	865c	41b

In each column, means which have similar letters do not have significant difference based on Duncan's multiple-range test at 5% probability level.

Apirus herbicide, by means of controlling the weeds and reducing competition, increased the number of grains per spike through increasing the number of spikelet per spike. In this herbicide, the number of grain in wheat spike was 33% more than the treatment without control (Table 5). The 1000-grain weight also increased significantly in this treatment in relation to other herbicide and the unweeded treatment.

Table 6. Interactive effect of herbicides and nitrogen rates on wheat grain yield and yield components.

N (kg ha-1)	Herbicides	S.m-2	Sp.S-1	G.Sp-1	GY (g.m-2)	BY (g.m-2)
50						
	Tapik+Granestar	270d	11d	22c	289g	757ef
	Tapik+Duplosan Super	301cd	15ab	18d	489de	988def
	Apirus	318cd	16a	32ab	465de	983def
	Control	314cd	11d	22c	286g	697f
100						
	Tapik+Granestar	337cd	13bcd	23c	427de	882def
	Tapik+Duplosan Super	348bc	16a	26bc	514cd	1137cd
	Apirus	415ab	17a	34a	615b	1343bc
	Control	329cd	12bcd	22c	334fg	795ef
150						
	Tapik+Granestar	349bc	13bcd	27abc	600bc	1162cd
	Tapik+Duplosan Super	374bc	17a	26bc	618b	1174cd
	Apirus	459a	17a	34a	747a	1606ab
	Control	343bc	13bcd	24c	418ef	994de
200						
	Tapik+Granestar	376bc	14bc	29abc	620b	1396bc
	Tapik+Duplosan Super	414ab	17a	28abc	636b	1364bc
	Apirus	461a	17a	32ab	764a	1742a
	Control	352bc	13bcd	22cd	412ef	976def

In each column, means which have similar letters do not have significant difference based on Duncan's multiple-range test at 5% probability level.

The highest and the lowest biological yield of wheat belonged to Apirus and T+G treatments respectively (Table 5). The wheat biological yield difference between treatments T+G and T+D was not significant. The completion between weed and wheat decreases the crop biomass and the herbicide high efficiency increases the biological yield of crop by means of decreasing the competition between the weed and the crop (Moradi-Talavat *et al.*, 2010).

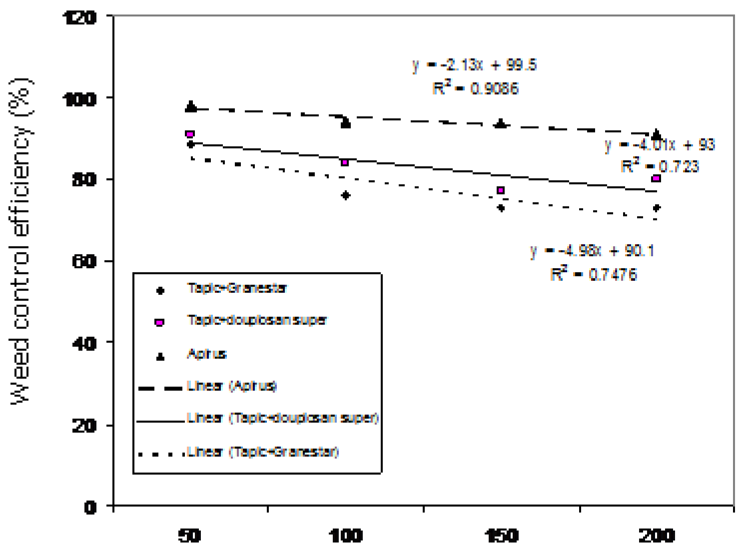

Fig. 1. Changes trend of weed control efficiency in herbicide treatments with different nitrogen levels.

Harvest index difference was only significant between herbicide treatments (Table 4). Herbicide consumption, due to more effect on grain yield in comparison with crop biomass, led to the increase of harvest index in relation to the unweeded control (Table 5).

Generally, the results of this research indicated that the observed reductions in grain yield and yield components were higher in the completely unweeded plots due to the higher weed density and the consequent high competition with wheat. Apirus was significantly more efficient than other herbicides in controlling narrow and broad-leaf weeds. This herbicide had nearly similar efficiency at different N rates in comparison with other herbicides while in other herbicide treatments, the increase of N rates and biomass of the weeds decreased the weed control efficiency. On the other hand, in recent years some weeds like wild oats are reported to be resistant to Tapik herbicide in Iran (Zand *et al.*, 2006). Consequently, it seems like that using new dual-purpose herbicides such as Apirus will lead to the increase of control efficiency and the decrease of development of species which are resistant to older herbicides such as Tapik and Granestar.

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