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Optimizing Weed Control by Integrating the Best Herbicide Rate and Bio-Agents in Wheat Field

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Abstract: *Cutting of herbicide dosage without compromising grain yield can cause to less environmental pollution and lower production costs. Field experiments were laid out over years 2012 - 2014 to appraise the efficacy of reduced rates of a new generation post-emergence herbicide verdict in combination with biocontrol agent to suppress three major weeds (Chenopodium album, Avena fatua and Capsella bursa-pastoris) in wheat (Triticum aestivum L.) under the condition of Non-chernozem zone, Moscow region. Below labeled rate 0.3 kg/ha^{-1} plus bio-agents was quite effective in suppressing total weed populations. This study revealed that a favorable level of weed reduction in wheat fields was obtained when lower herbicide rate 0.3 kg/ha^{-1} and bio-agents were used, that was comparable to the result which achieved for registered verdict dose as 0.5 kg/ha^{-1}. Hence, despite the higher weed reduction efficacy was obtained with herbicide in registered label dose plus biocontrol agent, but the differences were not significant compared to below herbicide dose 0.3 kg/ha^{-1}. Meanwhile, the best energy output (90.3 GDj/ha^{-1}), agricultural efficiency (19.9%) and wheat grain yield 7.80 t/ha^{-1} were achieved when reduced herbicide rate 0.3 kg/ha^{-1} combined to biological agent were applied.*

Keywords: *Weed, Reduced Herbicide Rate, Wheat Yield, Agronomical Efficiency, Energy Output*

1. Introduction

Herbicides are the dominant tool used for weed management in modern cropping systems; they are highly effective on most weed populations but are not a complete solution to the complex challenge that weeds present. The overuse of herbicides has led to the rapid evolution of herbicide resistance (Beckie 2006; Egan et al., 2011). Herbicides in Labeled doses are often selected to ensure a high level of weed suppression over a wide range of environmental conditions, weed growth stages, and weed species (Blackshaw et al., 2006).

Belles *et al*. (2000) determined that a 50% rate of tralkoxydim suppresses more than 85% of wild oat (*Avena fatua* L.) in barley field. O'Donovan *et al*. (2001) also indicated that tralkoxydim at reduced rates can provides an acceptable reduction of wild oat. Study of several herbicides (fluroxypyr; diflufenican plus MCPA and Clopyralid plus 2, 4-D) efficacy in various doses to control broad-leaved weeds in wheat in Iran revealed that the control of *Galium tricornutum* is above 85% for the highest herbicide dose, but drops to below 50% at the lowest dose and these three herbicides used at the highest dose also control *Lamium amplexicaule* and *Descuraina sophia* at over 82% (Zand *et al*., 2007). Nevertheless, majority of herbicide molecules at lower than- recommended doses are effective enough to provide satisfactory weed control without yield reduction (Walker *et al*., 2002; Auskalnis and Kadzys, 2006; Barros *et al*., 2007).

Increasing number of herbicide-resistant weeds (Basu *et al.*, 2004) makes it obvious that frequent use of a single tool for pest control not only leads to a preponderance of the most problematic species, but can basically shift the genetic composition of their populations. However, integrating control practices emphasizes the use of multiple strategies to address the causes of weed fitness, (Buhler 2002). Consequently, investigating for alternative cultural and biological practices has intensified (Hatcher and Melander 2003; Larsen *et al.,* 2004).

Biological strategies recommended alternatives to the application of chemicals that provide new environmental options weed control practices (Bailey and Mupondwa 2006, Boyetchko 2005). Biological weed control is determined as environment-friendly, utilizing host-specific control components towards weeds that prevent damage to host crops (Pleban and Strobel 1998).

2. Material and Methods

Field experiments were conducted on improving the strategies for post-emergence weed suppression in winter wheat (*Triticum aestivum*) were performed as an intensive farming technology during 2012 - 2014 in the Moscow Research Institute of Agriculture, Moscow area, Russia. The site was located at 55° 45′ N, 37°37′ E and 200 m altitude. Samples were taken randomly from different spots at 0 - 15 cm to record the initial characteristics of the experimental soil.

2.1. Field Layouts Details

Biological agents [bio-herbicide, bio-fertilize and bio-fungicide with anti stress activity to weather conditions and chemical treatments in combination with the various rates of new generation post-emergence herbicide ‘verdict’ (0, 0.2, 0.3 and 0.5 kg/ha-1) adjuvant 0.5 L/ha-1 was mixed to herbicide as a tank mix. All agents were used at the early stem stage of wheat, and, other cultural practices were typical of those used for commercial winter wheat production in Moscow region.

Variety of wheat cv. Moscovskaya 39 was sown in August 2012 and in the second and third year the same variety was sown in September 2013 and 2014, using densities of 5 million viable seeds per hectare. Formulation of herbicide verdict: meso-sulfuron-methyl 30 g/kg , iodine-sulfuron-methyl -sodium 6 g/kg and mefenpir –diethyl 90 g/kg. *Bioherbicide* Kemi: is a biological herbicide contains the microorganism *Colletotrichum* spp. Mentioned bioherbicide can be used mid and late season when most chemicals cannot be sprayed, the usual rate 3 kg/ha^{-1}. *Biofertilizer* Humi: is a humic fertilizer, contains humic acid and such ingredients as B, Mo, Co, Cu, S, I, Mn, Zn, this agent helps plants survive stress caused by weather conditions and chemical treatments. It also reduces the incidence of damage by pests and diseases and increases the yield; it can be applied at the rate of 1 L/ha^{-1}. *Phytosporin* is a bio-fungicide with anti stress activity to weather conditions and chemical and growth regulator activity, consisting of highly active spores of endophyte bacterium *Baccilus subtilis*. It is effective against a wide range of fungal and bacterial diseases. For winter wheat 1 L/ha^{-1} during tillering stage can be used.

2.2. Data Analysis

Weed density from 0.25 m² area of each net plot was counted each year at 30 days after treatments by the use of 50 × 50 cm² quadrate according to the method of European Weed Research Society. The whole weeds were dried in an oven at 70º C until constant weight was achieved for dry weight factor. *Chenopodium album*, *Capsella bursa-pastoris* and *Avena fatua* were as determined species for this study.

Analysis of variance (ANOVA) was used to assess the variation of the data. Duncan’s multiple range tests at P, 0.05 was used to compare the means and determine the significance of differences between variables using SAS (SAS institute, 2002) for Windows.

3. Result and Discussion

3.1 Weed Control Efficacy during 2013 - 2014

The higher efficacy was obtained with the maximum herbicide dose 0.5 kg/ha^{-1} plus bio-agents, but the difference was not high compared to the verdict dose 0.3 kg/ha^{-1}. Additionally, the lowest herbicide rate 0.2 kg/ha^{-1} combined with bio-agents had a significantly lowest control efficacy on declining of weed species: *Cenopodium album*, *Capesella bursa-pastoris* and *Avena fatua*. Although the highest weed control was achieved with the labeled dose of verdict (0.5 kg/ha^{-1}), intermediate herbicide dose 0.3 kg/ha^{-1} + bio-agents also provided a desirable reduction about all three weeds varieties (Figure 1, 2). Hence, below registered dose of herbicide could be used as a cost effective, economical and environmentally friendly approach to minimize weed pressure in crop fields. As in our study, the efficacy of cutting rates of herbicide groups has been determined by other authors (Barros *et al*. 2009; Barros *et al*. 2011; Kieloch and Domaradzki 2011; Buczek *et al*. 2012).

According to the results of this study, despite the highest weeds control efficacy was obtained with the registered dose of herbicide, below-labeled rate 0.3 kg/ha^{-1} plus biological agents also caused acceptable weed reduction about entire weeds varieties (Figure 1, 2). There are examples where herbicides are used at doses that do not often cause such high weed suppression. Indeed, using herbicide rates can vary markedly between countries and enterprises. For instant, doses of herbicide in Australia are often 50% of that in other nations.

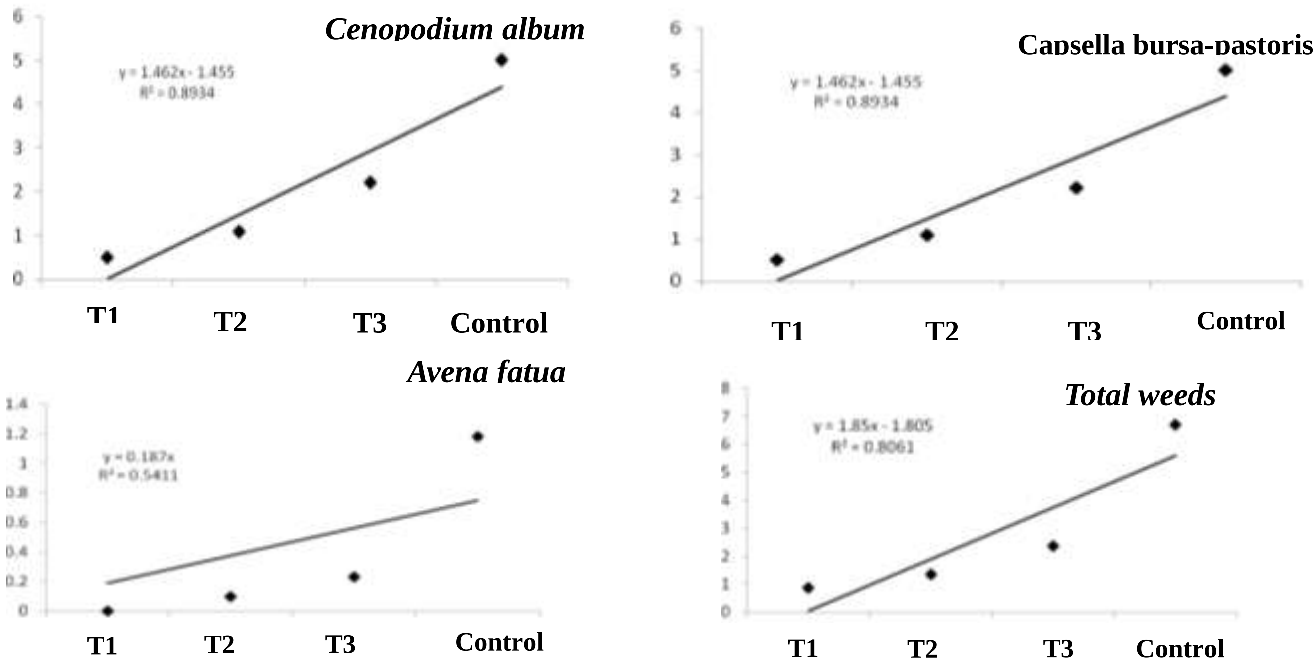

Fig 1. Weed dry weight affected by treatments 30 days after applications in 2013 (plant/m^{-2}).
Abbreviations: T1, T2, T3 are herbicide dose 0.5, 0.3 and 0.2 L/ha^{-1} respectively plus bio-agents.

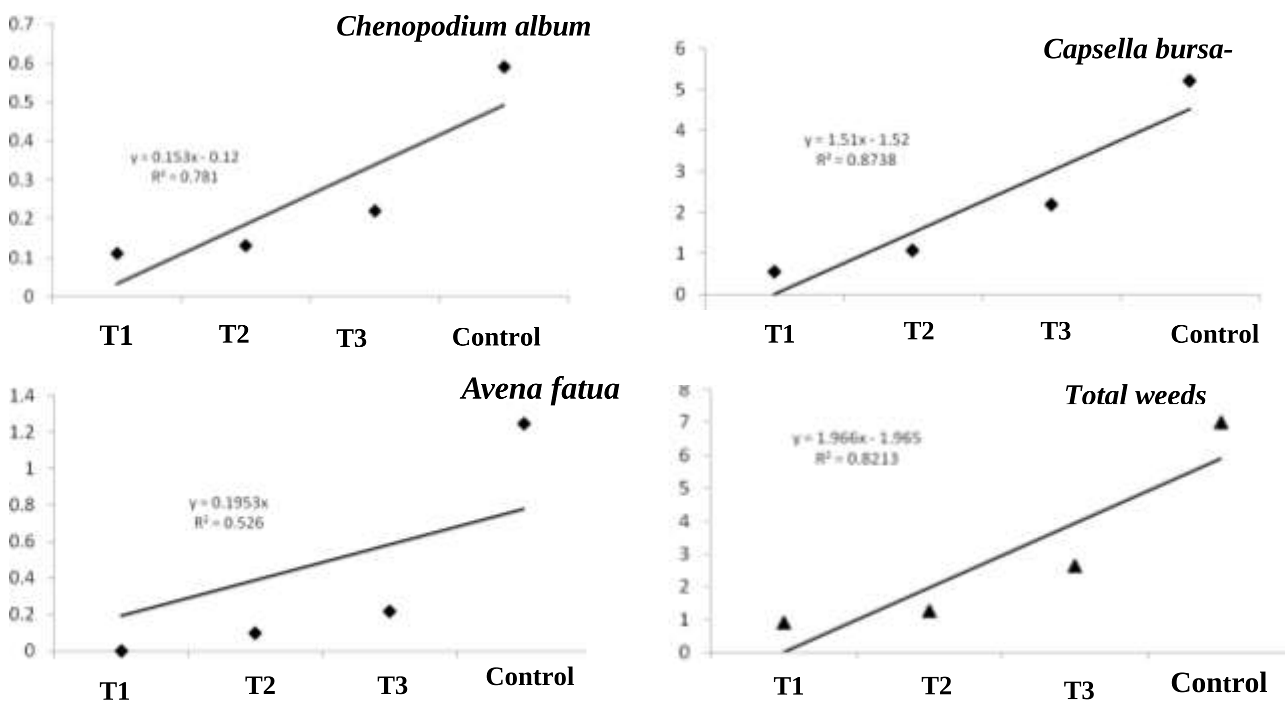

Fig 2. Weed dry weight affected by treatments 30 days after applications in 2014 (plant/m^{-2}). *Abbreviations: T1, T2, T3 are herbicide dose 0.5, 0.3 and 0.2 L/ha^{-1} respectively plus bio-agents.*

However, the labeled rate for diclofop in Australia is 375 g ai ha21 compared with 640 g ai ha21 in the United States and 900 g ai ha21 in France (Bayer 2010). Moreover, 28% of the crop fields in Canada manage weeds with reduced dose of herbicides (Beckie 2006). In addition to dose cutting, environmental variability under field conditions for soil residual herbicides can result in lower than- normal doses of herbicides being used to weed populations (Zhang et al., 2000).

Biological agents cannot replace chemicals, or any other weed control tools, hence, biological agents should be combined to other control techniques (Medd et al., 2001).

3.2 Biological Efficiency of Treatments during 2013 - 2014

Estimating the biological efficiency of verdict combined to bio-agents 30 days after application demonstrated that herbicide 0.5 kg/ha^{-1} combined to bio-agents reduced weeds dry weight 90 - 91% and density 86.6 - 87.5% compared to the control during 2013 – 2014 experimental years, additionally, dry weight and density of weeds were desirably declined in comparison with control when bellow labeled herbicide rate 0.3 kg/ha^{-1} was used (Table 1).

According to the result, it can be recommended to reduce herbicide rates combined to biocontrol agents in order to improve weed control programs, this point in addition to control weeds in a proper way can diminish environmental pollution, herbicide resistant weeds and ultimately achieve sustainable agricultural system. Some investigations have demonstrated satisfactory weed reduction and also acceptable yields, while herbicides are applied at lower than registered rates (Bostrom and Fogelfors, 2002).

Results of this study might be due to the integration of biological agent to herbicide. It is necessary to realize that a bioherbicide or any biological weed control techniques are not an analogue of a chemical. Nevertheless, bioherbicides or any other biological practices have to be combined to other control tools in an integrated weed management approach. In this regards, recent studies have illustrated that low rates of herbicides could result in faster evolution of herbicide-resistant weed (Manalil et al., 2011). So, reducing herbicide rate is better combined to integrated techniques.

TABLE I: Biological Efficiency of Treatments 30 Days after Applications during 2013 -2014.

Treatments	**Yr**	*Density plant/м$^{-2}$*	*Dry weight gr/м$^{-2}$*	*Percent of weed reduction compared to control*	
				Density	*Dry weight*
T 1	2013	7.5	0.6	87.5	91
	2014	8	0.7	86.6	90
T 2	2013	13	1.3	79	82
	2014	13	1.2	78.3	83
T 3	2013	27	2.3	55	65.6
	2014	25	2.6	58	62.5
T 4	2013	60	6.7	-	-
	2014	60	7	-	-

Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha^{-1} plus bio-agents and control respectively.

Energetic efficiency. Energetic efficiency is an important factor for sustainability of the cropping systems, hence, effective energy use allows financial savings (Pervanchon *et al.,* 2002) and can lead to environment-friendly production systems (Gundogmus and Bayramoglu, 2006). For the mentioned reason, energy input and output are essential index to specify the energetic efficiency of crop productions (Rathke and Diepenbrock, 2006). In this study, the best energy output was obtained (90.3 GDj/ha^{-1}) when intermediate verdict rate 0.3 kg/ha^{-1} combined to biological components were used (Table 4).

TABLE IV: Energetic efficiency in winter wheat (Maskovskaya 39) variety, average for three yrs 2012 – 2014).

Treatments	Yield, t/ha	Energy output, GDj/ha^{-1}	Cost, GDj/ha	Energetic efficiency rate
T 1	6.97	85.0	10.0	1.7
T 2	7.40	**90.3**	10.7	1.8
T 3	6.83	83.3	9.8	1.7
T 4	6.17	75.3	8.9	1.8

Abbreviations: T1, T2, T3 and T4 are herbicide dose 0.5, 0.3, 0.2 L/ha^{-1} plus bio-agents and control respectively.

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